MAGPICK - magnetic map & profile processing.

User Guide.

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Last revised 07/26/01

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1 History and features of Magpick

1.1 Version 1.0 - 1996 -1998

Development of MagPick was started in the spring 1996. The initial idea was to provide an interpreter with a simple tool which could perform basic operations, such as:

- View a magnetic map with dynamic adjustment of a color scale in accordance with minimum and maximum grid data. Narrowing the data interval could also be accomplished if desired.
- Zoom of the different parts of the map and present them in separate windows; automatic change of the color scale to fit data range in the particular window;
- Simplify ”magnetic picking”. This was accomplished by allowing the user to select two points with a mouse and store them in the file. In many cases location of magnetic body is between minimum and maximum of magnetic field: therefore two points are needed to estimate location.
- Advanced ”magnetic picking”. The user selects regions where minimum and maximum are, and program automatically finds their exact positions.
- The removal option erases picks that has been made.

This first version of MagPick was ready about one week after initial design began. It was used to pick more then 1000 magnetic anomalies on map of Hamburg airport area. Sophisticated options such as fitting of observed magnetic field by model source were requested shortly. These new features were implemented in the framework of MagPick in the autumn of 1996, and Hamburg airport data was reprocessed. Each place of interest the user could automatically estimate positions of sources which were represented by set of uniform magnetized spheres. To check quality a synthetic magnetic field was calculated and compared with the observed one. At the same time attempt was made to estimate the mass of the sources. The problem of mass estimation is quite complex. A knowledge of susceptibility (κ) and remanent magnetization (J_r) is required, but these values have a very wide range for ordinary iron.

Further development of MagPick was resumed in November - January of 1997 - 1998. Many new features were implemented:

- Regional magnetic field was taken into account as linear function of coordinates. This allowed usage of the program directly on measured magnetic field, without subtracting the Earth’s main field.
- The results of inversion were presented as an electronic table (worksheet). Some simple forms of manipulation such as deletion, reading, undoing, etc. were implemented.
- Additional information in the form of lines, polygons, annotated points, clips can be drawn on the top of the magnetic map.
- Presentation of the field by annotated contours was developed.

- Option to load initial (profile) measurements and plot their geometrical positions on the top of the map was added. The profile graph view was was developed. The observed magnetic field can be viewed as set of linear graphs such as $T(x), T(y), T(l)$ and $T(p)$. Here T - field, x,y - planar coordinates of observed points, l - distance along profile, p - projection of the profile on given line.

- Inversion based on profile data was implemented. This means that all (or part) of profiles crossing a given window can be used to estimate the position of the magnetic source. Calculated and observed curves are plotted to see the quality of the solution.

- Point marking on graph/map profile view was added. The mark on the profile automatically appears on the map view and vise versa. Thus the space location of interesting points can be easily found.

- Printing/previewing on postscript printer was implemented.

MagPick was then used to process data of Hamburg harbor area which was collected during summer - autumn of 1997. Some places were examined by divers; in most of the cases the magnetic source was found around $\pm 30cm$ (in the plane) from the predicted point. Thus MagPick was proven to be a good tool for magnetic interpretation.

1.2 Version 2.0 - 1998 -1999

During this period MagPick was not used extensively. The most significant use was designing a pipe inversion. This was requested by "Geometrics" in spring 1998. This kind of magnetic source is more difficult for interpretation than magnetic dipole. It appeared that pipe locating is far more ambiguous. It is also more difficult for interpreter to deal with.

Here is some other improvements which were done that time:

- **Magpick** now can interpolate data from profiles to rectangular grid (therefore there is no need for additional interpolation program.) Currently two methods are available: gridding with tension (borrowed from GMT software) [1] and triangulation with interpolation (see [3] and [4].)

- For pipe and dipole profile based estimation data can be constrained by polygon drawn by user. This presently does not work for dipole fitting based on map data.

- Some improvements were done for map presentation and the number of available map views were significantly increased including:

  - A fast (but not accurate) contour drawing algorithm was brought into **MagPick.**
  - Set of uniform palettes is directly available and viewable with MagPick.
  - A new kind of color scheme ,*gradient palette*, was implemented. This control allows easy manipulation of the color scale, saving and loading from file and much more.
  - *Color equalization* method allows visualization of maps with maximum color contrast. Currently the feature is available with a uniform palette. This allows a color map to be produced where each color occupies an equal space, greatly increasing map resolution.

[1] Visit http://imina.soest.hawaii.edu/gmt/ No information was found forbidding usage of GMT code

  - A new kind of coloring, *color wrapping*, was added to the program. This provides a color wrap around certain range, for example, if range 0 - 500 then the data point 501 is colored the same as 1, etc. It visualizes the map in the greater detail.
  - *Shaded relief* mapping was implemented with a user-selectable position of light source.
  - *Illuminated map* presentation was added - the color map shaded in accordance with the light position.
  - Map drawing speed was increased.

- Easy profile loading (does not require hand preparation of profile list file) is now available. One data file now can hold more then one survey line. Program splits file into the lines during loading.
- *Stack plot* was added on top of magnetic map.
- Progress indicators were added to most time consuming operations such as data loading, color equalization, map, and profile drawing.
- Configuration file was re-written to be more user-readable than it was before.
- The set of tutorials (in this manual) has been added. Documentation has been improved.
- Numerous bug fixes.

After all these changes were assigned version number 2.0.

2 Installation.

MagPick is using the wxWin multi-platform library and therefore exists in two forms, U⋆nix (Linux) and MS Windows NT (95/98). U⋆nix like systems require compilation. Binary is available for MS Windows platform.

2.1 System requirements.

MagPick is C++ program which works under the U⋆nix operating system. The current version was developed and used under Linux (U⋆nix clone for PC's), and the gcc compiler version 2.7.2 and above was used. It is necessary to have X11 running because MagPick is a full windows client. It is linked to the following X11 common libraries:

libXaw.so
libXmu.so
libXext.so
libXt.so
libICE.so
libX11.so
libXpm.so

Selection of the system libraries can be different for another operating systems (for Solaris2.x, for instance).

MagPick employs netcdf library to read grid netCDF files. Library is freely available. A copy of the latest released version of netCDF software can be obtained using a WWW browser or anonymous FTP from

ftp://ftp.unidata.ucar.edu/pub/netcdf/netcdf.tar.Z

Follow the instructions to install netCDF library on your machine.

To implement a graphics user interface (GUI), **magpick** uses wxWin C++ library version 1.6x , which can be found on:

http://web.ukonline.co.uk/julian.smart/wxwin/

There are different implementations of wxWin are available . Libraries can be based on standard toolkits: motif, xview (OpenLoolk) or Athena widget set (Xt). In general magpick could be compiled for any of these platforms, but a working version (described here) is compiled with wx-Xt libraries, version 166d. Follow the instructions to install wxWin library. During configuration make sure that the usage of Xlib is enabled. You will need wxgrid library which is part of wxWin. A nicer view of worksheet can be obtained obtain with a patch from :

ftp://ftp.aiai.ed.ac.uk/pub/packages/wxwin/contrib/wxgridd/wxgrid_d.tgz

It is worth checking your installation using test/demo programs that comes together with the library.

When you have all these libraries and gcc C++ compiler installed, you can start the compilation ofMagPick

2.2 Compilation.

Make a subdirectory and unpack file **magpick.tgz** with **gzip** and **tar** programs. Edit the file **makefile.xt** to match you site configuration. You will need to change the next variables in the makefile.xt:

- **WXDIR** points the root of your wxWin installation.
- **INC** points include files folder(s). If your netcdf library is not in the system place, set its include path too.
- **THISDIR** is current location where sources are.
- **LDFLAGS** linker flags (where all libraries can be found. This should be the path to wxWin and netcdf libraries).
- **LDLIBS** Selection of the libraries. If wxWin on your system requires additional libraries, you should alter this list.

After altering the makefile you can type:

make -f makefile.xt

and likely end up with the file **magpick_xt** which is executable version of the program.

2.3 MS Windows installation.

If you have the **magpick.exe** file the only problem you may have is with **ctl3d32.dll** library. At least two versions (for Win95 and NT) exist. You will need to find the right one for your platform. The next step is copying of this file into a windows system directory (probably `C:\WINNT\SYSTEM32` under NT and `C:\WINDOWS\SYSTEM` for 95/98 like systems). *Please note: this file can not reside in the same place as magpick.exe*. After files are in place everything should run.

Later versions of **magpick** also have a setup program based on Install Shield 5.0 free edition.

3 Basic operation of magpick

Here is some basic ideas behind MagPick:

- MagPick works with information that can be presented as a grid (files in SURFER ASCII, BIN and NetCDF format) and with information presented as set of profiles (simple ASCII files with space / tab separated). The grid information is compulsory: it provides ”schene” for presenting profile data. Some additional data (like road a map / costline) can be loaded on top of the grid data too.

- Loading of grid data is not complex. All you need is file in the format which can be read by MagPick.

- Loading of the profile data is more compilcated . You should a prepare *profile description file* to begin with. Alternatively MagPick can prepare this file for you but you’ll have less control. You do not have to load the map data to be able to load the profile data.

- As soon as the profile data is loaded it can be interpolated to create a grid file loadable into MagPick.

- You can set marks (*picks*) everywhere on magnetic map. These picks might represent places you consider to be interesting. Picks can be saved into file and loaded again. You can delete a pick you don’t like. Picks can be exported into some formats readable by SURFER and AutoCAD. The name of the program, MagPick was given because of this feature.

- You can *estimate the location of magnetic sources*. To do this some approximations should be used. Presently MagPick allows two kinds of sources: *Magnetic dipole* which is good for a local magnetic source(s) and *magnetic line* which fits objects like pipes. You can find a geometrical location and an amplitude of the source, and in some cases its mass.

  Results of estimations are viewed as worksheets and can be saved orloaded from files as well as exported.

Under U⋆nix start **magpick** with command line :

magpick_xt

or under MS windows with (in this case you also can start it from Windows Explorer or create shortcut to desctop)

magpick.exe

MagPick first tries to read the file **magpick.ini** from the MS Windows directory (windows 95/98) or from user profile directory (Windows NT). Under U⋆nix like systems MagPick reads the file **.magpick** from user home directory. These files hold settings of the program (which can be altered by different dialogs). This file is written right after **magpick** exits. If file is not found, all defaults are assumed.

If start is successful, you will see a small window with a menu under U⋆nix (X does not support MDI interface) or an empty multi document window (MDI) window under MS Windows. This is the root window of MagPick which remains unchanged during the session (U⋆nix). Besides this root window you can have as many additional windows as you wish. These windows are called *views*. The current version of MagPick allows you to have three types of views:

1. **Map view.** This is a 2-D coloured or black and white map of the grid with additional information if desired. This view is independent from all other windows.

2. **Profile browser view.** If a set of profiles is loaded into the program, you can browse each one of them as 2-D linear graph. This view might be linked or not with map views(s).

3. **Profile inversion view.** You can see all (or part) of the profiles which cross the parent map view. This view dependents on the parent map view. Only one profile inversion view is allowed for a given map view.

The last views are unaccessible before the profiles are loaded. This means that when the program opens you are able to create only the map view. When you choose **New...** item, a new empty window with the same menu appears on the screen. If the profiles were loaded, then by choosing **New...** you can the type of view you want.

In the following sections a discussion is developed in detail for each mode of operation.

3.1 Magpick as map (grid) viewer.

Just after the start of MagPick go to **New...** and request a new window. Then click **Open...** and you can choose netCDF or SURFER (ASCII or binary) grid file to load into window. After the loading is completed (which take time depending upon size of the file) you end up with a colored map on the screen. Alternatively, you can click **Open...** point directly. If you choose this option in the root menu a new window is created automatically.

You can change size of the window and therefore resolution by means of **Options.../Size...** item. Here you are able to choose three values: horizontal size of one grid cell on the screen (in pixels), vertical and zoom factor when you are zooming in part of the map. Be careful: large sizes can consume all the memory of the computer. You may find *Autoscale on zoom* is useful . It means when you create new window by zooming part of the old window color scale into this new window will be choosen in accordance with local minimum and maximum. This may allow you see fine details in the view. This kind of ”color zooming” is very useful.

The first view you see may not be what you want. To adjust color scale, mesh lines, contours appearance and other items you should go to **Options.../Settings...** and work in ”Common parameters” dialog box. You can see it on figure 1

Here is full explanation of all the controls:

1. **Field direction.** Some constant angle value which is used for simple picking (see below).

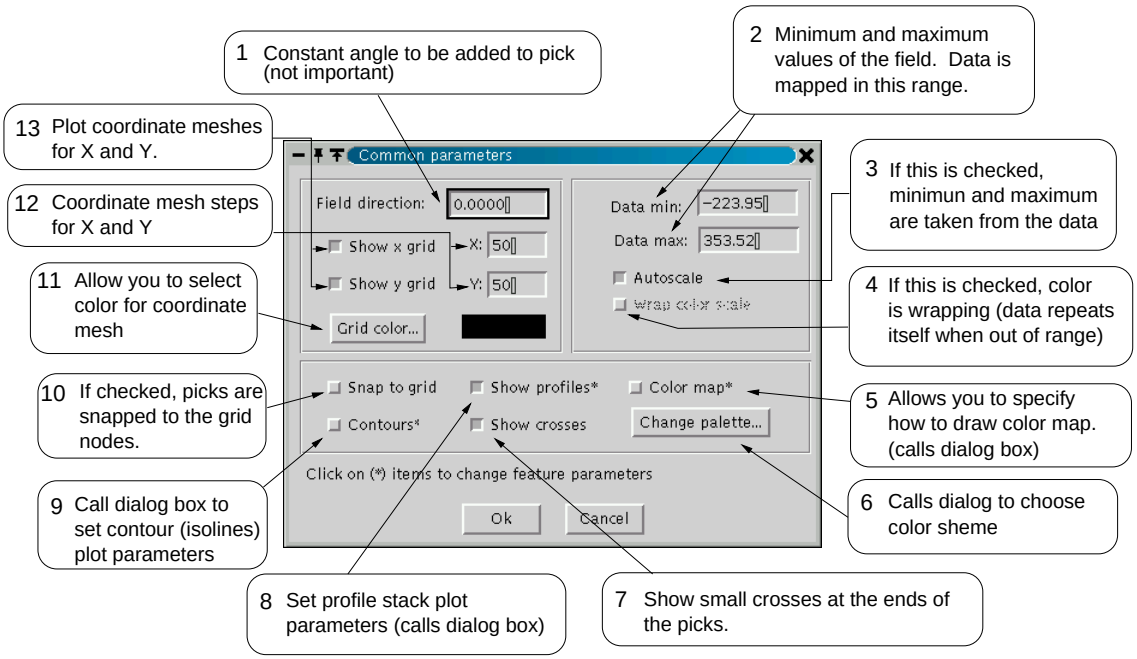
1 Constant angle to be added to pick (not important)
2 Minimum and maximum values of the field. Data is mapped in this range.
13 Plot coordinate meshes for X and Y.
12 Coordinate mesh steps for X and Y
11 Allow you to select color for coordinate mesh
10 If checked, picks are snapped to the grid nodes.
9 Call dialog box to set contour (isolines) plot parameters
3 If this is checked, minimun and maximum are taken from the data
4 If this is checked, color is wrapping (data repeats itself when out of range)
5 Allows you to specify how to draw color map. (calls dialog box)
6 Calls dialog to choose color sheme
8 Set profile stack plot parameters (calls dialog box)
7 Show small crosses at the ends of the picks.
Common parameters
Field direction:
0.0000
Data min:
-223.95
Data max:
353.52
Show x grid
X:
50
Show y grid
Y:
50
Autoscale
Wrap color scale
Grid color...
Snap to grid
Show profiles*
Color map*
Contours*
Show crosses
Change palette...
Click on (*) items to change feature parameters
Ok
Cancel

Figure 1: Common parameters dialog box

2. **Data min - Data max** User - defined limits for plotting of the grid data. Unless ”autoscale” is checked, color palette is scaled to that range; all data above **Data max** is drawn with maximum color, all data below **Data min** is drawn with minimum color. This parameters has no effect if **autoscale** is checked.

   Data min - Data max have different meaning if you choose *Wrap color scale*.

3. **Autoscale** If checked, the color palette is scaled to the real minimum and maximum of the data in the current window. (Note - only the data *into* window is used to determine min and max).

4. **Wrap color scale** This provides a ”color scale wrapping” and the ability to see fine details in the map. It works like this: say, your data is in the range from 0 to 2000. You have set *Data min:* 0 and *Data max:* 200. This means that all the available color scale gets mapped into this range. Now what happens when we need to map cell with value 201? It gets mapped the same way as a cell with value 1. And so on. The map obtained in this way has ambiguous colors but allows more structure to be viewed.

5. **Color map** This controls the appearance of the color map (or disables the color map completely). This control is marked as (*); it means when you click on it to check an additional configuration dialog box appears. In this dialog box you can choose several modes to draw a color map. These are choices you have:

   - *No color map*. Simple: does not draw it at all.
   - *Simple color map*. Each data value is mapped into a color without any tricks (except autoscale and possibly wraping).
   - *Shaded relief*. This produces a picture as it would be if your data presents a surface shaded by a light source. The light source parameters (*azimuth* and *elevation*, degrees) can be set

as well. You also have to set the *Data scale* (in many cases value 1-10 is ok, but you might try different ones to find the best value).

You should use the *Uniform palette* for this kind of plot.

- *Color illuminated map* A simple color map can be combined with the effects of shaded relief. It may look very impressive (especially for topography data.)

6. **Change palette...** Calls the dialog box which allows you to choose the type of color mapping (*Uniform* or *Gradient*). *Uniform* is defined as a pre-defined color scale (spectra). The data gets simply mapped into that color scale. You can choose type of palette you like (0-41) and if *Equalize colors* is checked MagPick will apply non-linear color mapping based on the data distribution. This is particularly useful when the data has spikes. It allows you to see details better.

   The *gradient* method gives you much more control on coloring, but does not work with color equalization. When you choose this option you can use the color scale editor to compose the best palette.

7. **Show crosses** If checked, picks are shown as black lines with two small crosses at the ends.

8. **Show profiles** If profiles are loaded, they are normally drawn above the magnetic field. In some cases the can completely obscure the picture. Check it off to avoid drawing. This checkbox calls as well *Profile plot parameters* dialog which controls the stack plot if you need it (see below).

9. **Isolines** If checked, the contour plot is drawn on top of the magnetic map. When you check it an additional dialog pops on the screen to specify plot parameters (see below for details).

10. **Snap to grid** The program shows only positions of the *centre* of the cell where mouse pointer is (default). This way picking is limited only by centres of the nodes of the grid. To avoid this, check box off.

11. **Grid color...** allows changing the coordinate mesh color.

12. **Show X Y grid** If checked, the coordinate mesh will be drawn on top of the map.

13. **Mesh steps**. This were intervals for coordinate meshes are entered.

Here is a description of the isolines (contour plot) parameters dialog box (see figure 2)

1. **Fixed values/Automatic** To draw isolines, you can choose pre-defined levels or you can set the total number of isolines. In latter case levels are chosen automatically in accordance with minimum and maximum data values in the window. and the *Total* number of lines (contours). Thus if *Automatic* is checked, then you do not have to think about range of your data. Contours can have odd level values.

   If you choose *Automatic* then all controls labeled with a * on figure 2 do not affect the plot appearnce.

2. **Total** If you go with *Automatic*, you can choose the total number of contours used to plot a picture.

3. **Min., Max** Minimum and maximum values for contour lines.

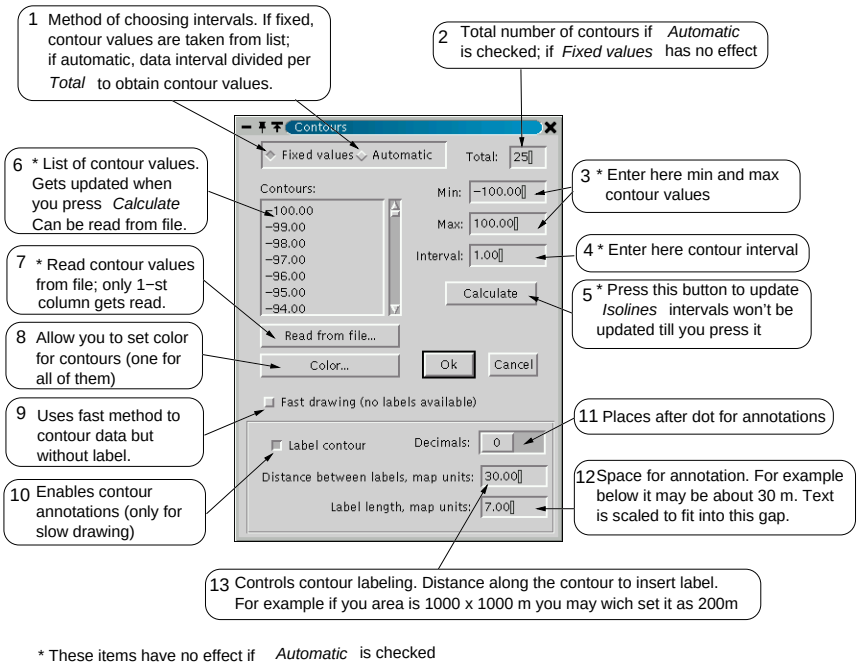
1 Method of choosing intervals. If fixed, contour values are taken from list; if automatic, data interval divided per Total to obtain contour values.
2 Total number of contours if Automatic is checked; if Fixed values has no effect
Contours
Fixed values
Automatic
Total:
25
Contours:
Min:
−100.00
Max:
100.00
Interval:
1.00
−100.00
−99.00
−98.00
−97.00
−96.00
−95.00
−94.00
Calculate
Read from file...
Color...
Ok
Cancel
Fast drawing (no labels available)
Label contour
Decimals:
0
Distance between labels, map units:
30.00
Label length, map units:
7.00
6 * List of contour values. Gets updated when you press Calculate Can be read from file.
3 * Enter here min and max contour values
4 * Enter here contour interval
5 * Press this button to update Isolines intervals won't be updated till you press it
7 * Read contour values from file; only 1−st column gets read.
8 Allow you to set color for contours (one for all of them)
9 Uses fast method to contour data but without label.
10 Enables contour annotations (only for slow drawing)
11 Places after dot for annotations
12 Space for annotation. For example below it may be about 30 m. Text is scaled to fit into this gap.
13 Controls contour labeling. Distance along the contour to insert label. For example if you area is 1000 x 1000 m you may wich set it as 200m
* These items have no effect if Automatic is checked

Figure 2: Isoline parameters dialog box

4. **Interval** Interval between contours. Data levels are distributed uniformly between *Min* and *Max* with this interval.

5. **Calculate** After you entered *Min.*, *Max.*, *Interval* their values have no effect till you press *Calculate*. Program calculates new levels; you can see them in list box *Contours.*

6. **Isolines:** Current list of levels for contour plot. It can be calculated or loaded from file.

7. **Read from file...** If you use custom selection of the levels, you have to prepare ASCII file with desired values. Only the *first* column of such a file will be read, rest of the string is not significant. Results are displayed in the *Contours*

8. **Color...** The default contour color is black. Press the *Color.*. to access the color dialog box and select another color. All contours are drawn with same color.

9. **Fast drawing** If this is checked a fast (but not accurate) algorithm is used to draw isolines (2D version of marching cubes). This does not allow labels but speed is much greater. It is recommended recommend to check this box in all cases when labels are not required.

10. **Label isolines** If this control is checked, the program will annotate contours. Note that it works only when ”slow” method of drawing is used.

11. **Decimals**. This provides selection of the decimal point you wish for annotations. For the magnetic field it is normally zero.

12. **Distance between labels, map units** This controls how labels are drawn. Program counts distance along each contour line; when this value exceeds the limits it places a label. You should specify this distance in your XY units.

13. **Label length, map units** To place annotation text the program makes a gap in the contour line. Text is scaled to fit into this gap. This is were you set gap size and therefore (inderectly) the label size too.

You can plot profile lines (with optional stack plot) on top of the magnetic map. Here is description of the dialog box which controls the profile plot parameters. This gets called from *Common plot parameters* dialog box by clicking on the *Show profiles* check button (see figure 3).

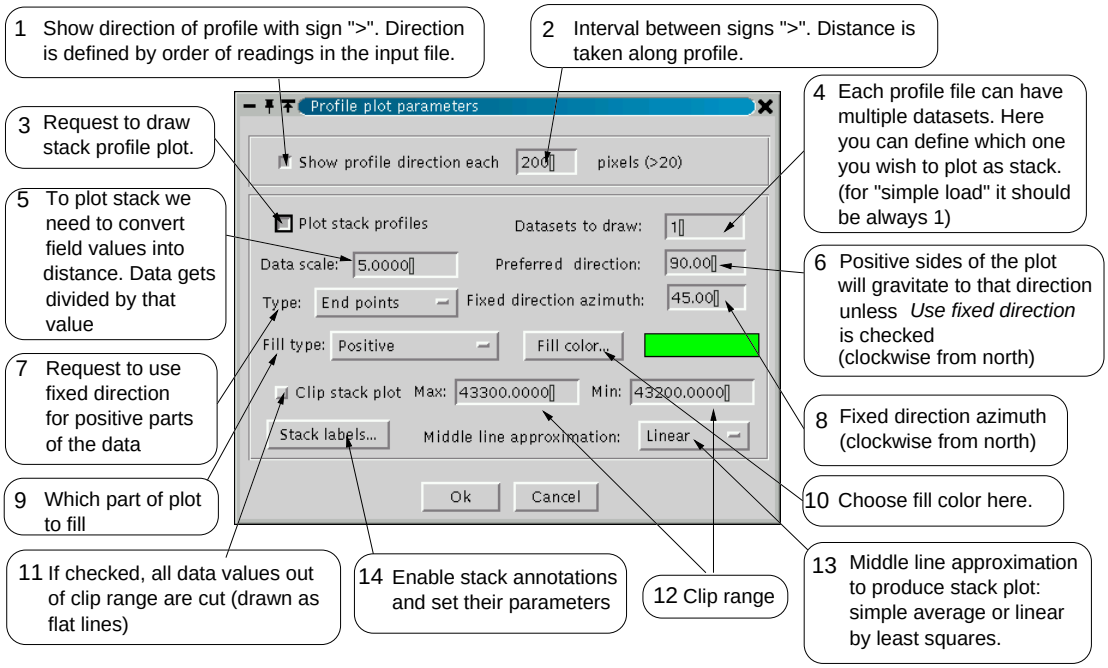
1 Show direction of profile with sign ">". Direction is defined by order of readings in the input file.
2 Interval between signs ">". Distance is taken along profile.
3 Request to draw stack profile plot.
4 Each profile file can have multiple datasets. Here you can define which one you wish to plot as stack. (for "simple load" it should be always 1)
5 To plot stack we need to convert field values into distance. Data gets divided by that value
6 Positive sides of the plot will gravitate to that direction unless Use fixed direction is checked (clockwise from north)
7 Request to use fixed direction for positive parts of the data
8 Fixed direction azimuth (clockwise from north)
9 Which part of plot to fill
10 Choose fill color here.
11 If checked, all data values out of clip range are cut (drawn as flat lines)
14 Enable stack annotations and set their parameters
12 Clip range
13 Middle line approximation to produce stack plot: simple average or linear by least squares.
Profile plot parameters
Show profile direction each
200
pixels (>20)
Plot stack profiles
Datasets to draw:
1
Data scale:
5.0000
Preferred direction:
90.00
Type:
End points
Fixed direction azimuth:
45.00
Fill type:
Positive
Fill color...
Clip stack plot
Max:
43300.0000
Min:
43200.0000
Stack labels...
Middle line approximation:
Linear
Ok
Cancel

Figure 3: Stack profile parameters.

1. **Show profile direction** To see how data was taken MagPick will show your profile direction estimated from the samples order in the file (note that if your file has time reversed, it would be opposite). Check this box to see the profile direction.

2. **Interval between signs**. Interval, in pixels, to place the sign $>$ displaying profile direction. Distance is taken along the line. This value can not be less then 20 pixels (If less then 20 very dense marks appear). Recommended is 100-200 pixels.

3. **Plot stack profile** This box should be checked if you wish to see a stacked plot. If not checked the rest of the controls in this window are disabled.

4. **Datasets to draw** Each profile file can have several datasets inside. Thus the word ”profile” does not mean a sequence of $X, Y, Z, field$ values but $X_i, Y_i, Z_i, field_i$ were i is the dataset number. You can select which data set you wish to see as a stack plot. [2]

5. **Data scale:** Data has to be scaled to be plotted together with coordinates. This value is needed to scale data to the length units. MagPick *divides* the data value by this value before stack profile plotting. It converts data units (mostly nT) to length unist (meters).

[2]This requires a good understanding of how magpick handles profile data. In many cases the data set number is just 1

You may need to experiment with it to obtain the best plot.

6. **Preferred direction:** This controls where positive parts of the anomalies will ”gravitate”. if positive anomaly direction (defined by one of the three methods described below) is between $-90^o + 90^o$ from this direction it is mapped. If it is not that it gets flipped before plotting.

   If *Use fixed direction* is not selected then MagPick estimates direction of data plotting based on perpendicular to the track. If the positive anomaly is between -90 +90 degrees range from *Preferred direction* it is plotted; if not it gets flipped before plotting.

   Please note that this method requires a smooth enough track line which is not always available (especially for data acquired with GPS). Fixed direction is taken clockwise from north.

7. **Type:** This allows to select method for finding plot direction for the anomalies. Choices are *Normal to path*, *Fixed direction* and *End points*. If *Normal to path* is selected then field is plotted perpendicular to the path at every point. *Preferred direction* value is used to distinguish between positive and negative anomalies. This method requires a smooth enough track line which is not always available (especially for data acquired with GPS). Small irregularities in the positions result in big spikes on stack plot.

   If *Fixed direction* is selected then positive anomalies are simply plotted in that direction, and negative ones are plotted in opposite direction. Angle is taken clockwise from North. *End points* works similar, but direction is found by the program based on end points of the line. In latter case *Preferred direction* is important - it allows proper handling of lines doing in opposite directions (example: lines going North - South and South - North; if *preferred direction* is 0^o then positive anomalies on adjacent lines are plotted in opposite directions; *preferred direction* should be 0^o or -90^o)

   Both *Fixed direction* and *End points* do not depend on quality of GPS track.

8. **Fixed direction azimuth:** Value which defines fixed direction.

9. **Fill type:** At your request, part of the plot can be filled with a color. Here you can specify part of the anomaly to fill: *positive*, *negative* or *No fill*. It is also possible to plot only filled parts of the field: select *Positive, no line* or *Negative, no line*

10. **Fill color:** Invokes the color chooser dialog box which allows you to define the fill color.

11. **Clip stack plot** In some cases (big spikes for example) the plot can be contaminated with data you do not want to see. To avoid this, you can clip the stack plot. All values out of range will be plotted parallel to the track line.

12. **Min:, Max:** Enter clip values here for the plot if you would like it to be clipped.

13. **Middle line approximation** To prepare a stack plot the program first must estimate which values are plotted on the right part of the path and which are on the left. Total Earth’s magnetic field is always positive and therefore should be transformed to make it suitable for such a presentation. The simplest way to calculate the average value for the profile and subtract it from the field thus producing positive and negative anomalies. However this method would lead to unacceptable results if field has a regional trend. For example, a slow increase from West to East (see figure 4). Plate (a) shows a magnetic field as distance along the profile or time. There are few anomalies with a linear increasing background. Plate (b) shows what one can get if a

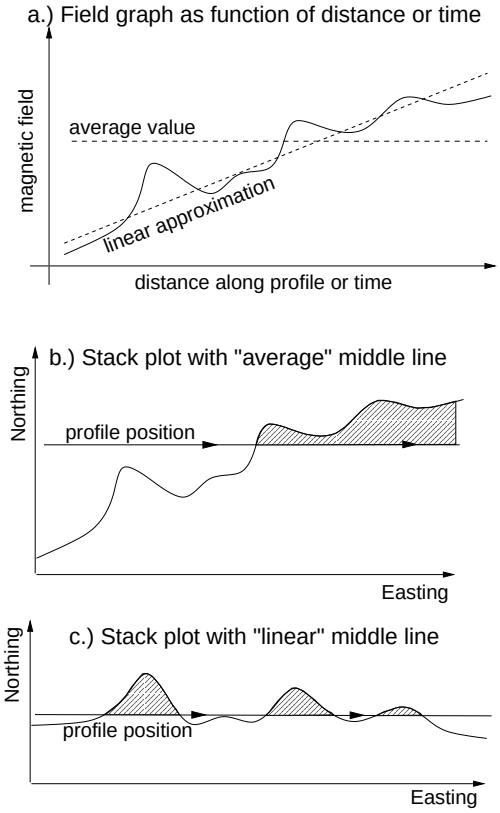

Figure 4: Different methods of creating stack profile plot.

simple average is used. A better way is use the linear approximation for the background as in the example on plate (c). [3]

14. **Stack labels** After a stack plot map is plotted it might be difficult to find what the anomaly values were. To make it easy **magpick** can automatically draw dimension lines on minimum and maximum points. Press this button to call the stack labels dialog and set the parameters of this feature. See figure 5 for an example of stack labeling.

To label a stack plot, MagPick searches for segments where the field is above or below middle line. For each segment it calculates extremum point. If extremum value is more than the user set limit, MagPick draws a dimension line with annotation. This can be a value above the middle line (relative) or an absolute value or both. However if there is not enough space to accommodate the label it won't be printed. The user can disable this feature by unchecking the box *Use stack plot labels* to select labeling threshold, set type of annotation, its color, text hight, and label suffix (see figure 6)

THe latest **Magpick** versions provide considerable improvements in map viewing. It includes two new kinds of data mapping: *Shaded relief* and *Color illuminated map*. . Both involve some simple shading calculations which the make map naev a better contrast. To use them, click on *Color map* check box in *Common parameters* dialog box. You may need to click twice to call *Color map draw mode* dialog. Here you have next choices (see figure 7):

1. **Drawing mode** Choose the type of the map you want to draw. The possible choices are:

[3]Magpick calculates average or linear approximation for each profile line separately. It leads to the breaks in the stack plot if continuous line was divided to the set of sub-lines.

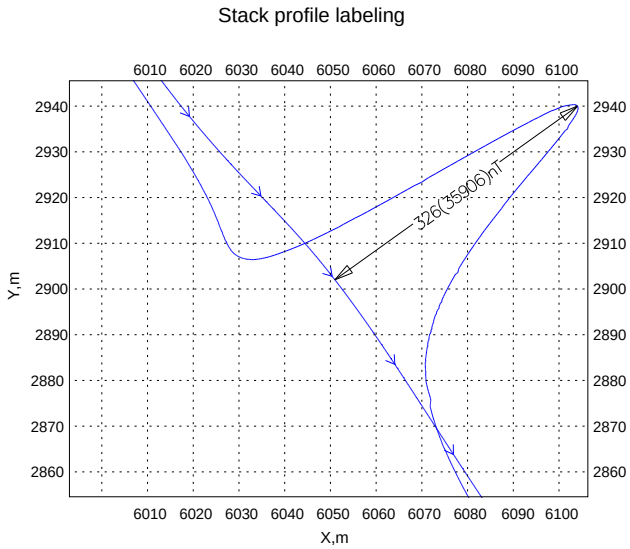

Figure 5: An Example of stack labeling. Both realtive and absolute values are printed. (actual magpick output)

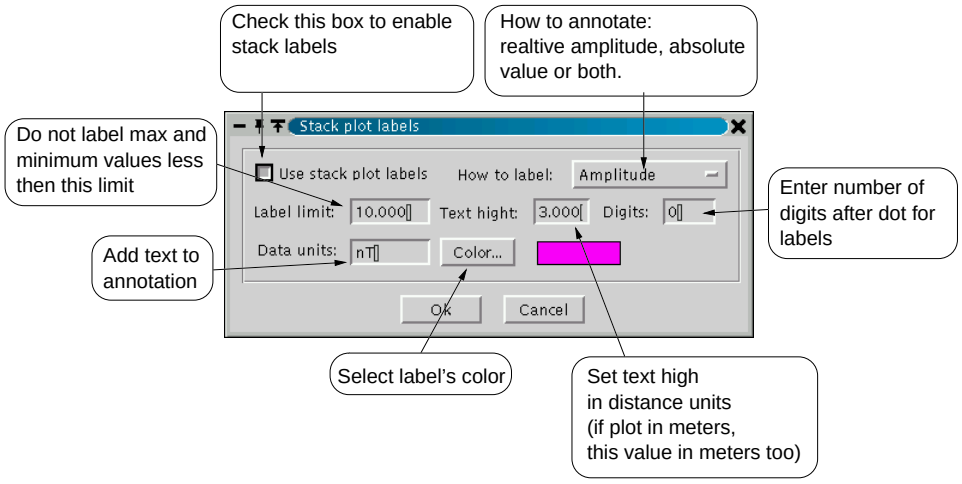

Figure 6: Stack label dialog.

- No color map. Do not draw it at all.
- Simple color map. There are no 3D effects here, just plain color image.
- Shaded relief. Black-and-white shaded surface. It allows you to see some details better.
- Color illuminated map. Similar to above, but colored.

2. **Light source parameters** To draw shaded maps, you must specify parameters of the light source such as its azimuth and elevation above horizon, both in degrees. Results are shown on the sun icon (4).

3. **Data scale** Before the shade calculations take effect, the data may need to be multiplied by some scale factor to improve the result. This control sets this value. You may need to try it few times to find the best setting.

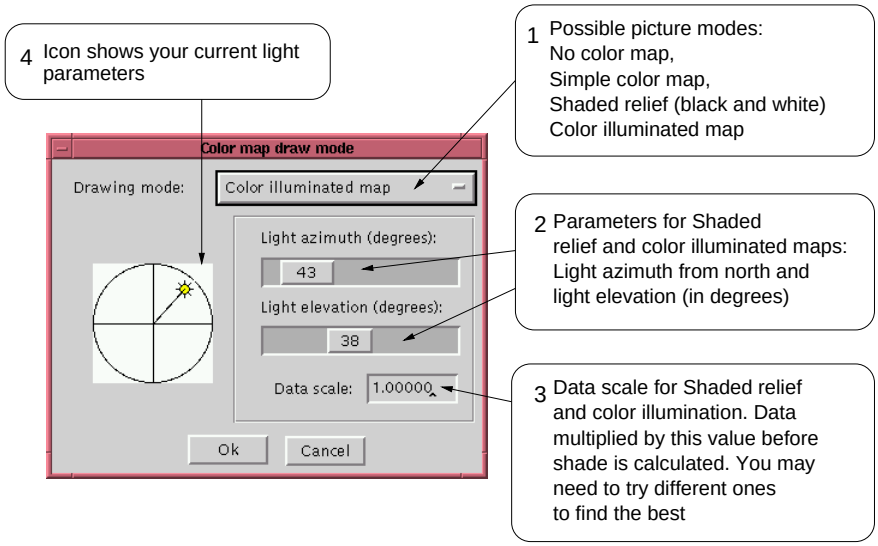
4 Icon shows your current light parameters
1 Possible picture modes:
No color map,
Simple color map,
Shaded relief (black and white)
Color illuminated map
Color map draw mode
Drawing mode:
Color illuminated map
Light azimuth (degrees):
43
Light elevation (degrees):
38
Data scale:
1.00000
Ok
Cancel
2 Parameters for Shaded relief and color illuminated maps: Light azimuth from north and light elevation (in degrees)
3 Data scale for Shaded relief and color illumination. Data multiplied by this value before shade is calculated. You may need to try different ones to find the best

Figure 7: Map drawing mode dialog.

MagPick supports two coloring schemes: *uniform* palette and *gradient* palette. In the first case the palette is defined by all its colors. Total number of colors can not exceed 255. There are a set of built-in palettes which are available in **Magpick**. In the second case the palette is based on a relative small number of color *nodes* each with its own color and data value. Color for the intermediate data values are interpolated. Gradient palettes can be saved or loaded from a file, and some set of build-in gradient palettes are available as well.

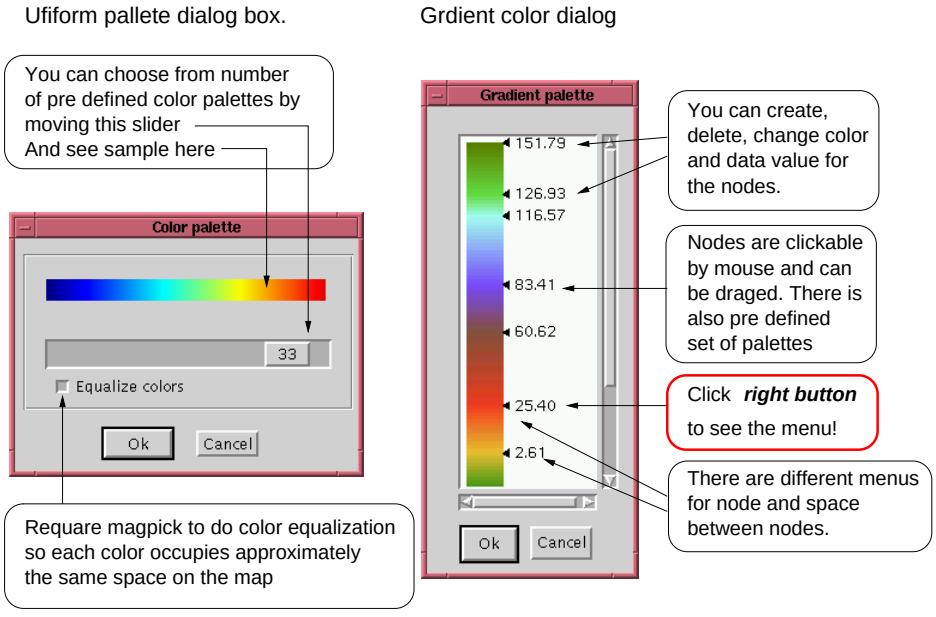
Ufiform pallete dialog box.
Grdient color dialog
You can choose from number of pre defined color palettes by moving this slider
And see sample here
Color palette
33
Equalize colors
Ok
Cancel
Requare magpick to do color equalization so each color occupies approximately the same space on the map
Gradient palette
151.79
126.93
116.57
83.41
60.62
25.40
2.61
Ok
Cancel
You can create, delete, change color and data value for the nodes.
Nodes are clickable by mouse and can be draged. There is also pre defined set of palettes
Click right button to see the menu!
There are different menus for node and space between nodes.

Figure 8: Uniform and gradient palette setup.

MagPick has a flexible tool to deal with a gradient palette (see figure 8), but uniform palette has the advantage: ability of color *equalization*. The goal of equalization is constructing of image where

single color occupies the same area as each other. Equalization provides an enhanced color image, and even small details can be seen immediately.

To invoke these options, click on *Change palette...* button in the *Common parameters* dialog box. You will be prompted for the type of palette you are going to use. Then end up with either dialog (figure 8).

You can zoom part of the window if you wish. To do so, choose **Edit.../Zoom**. You will see that the mouse cursor has a shape of a magnifying glass. Press the left button and drag the mouse around area you would like to zoom. After you release the mouse button a new window with the selected region appears on the screen. It can be zoomed again. It is important to understand that *all windows created by zoom share the same array (map) of data.* Several arrays can be opened at the same time. If you decide to close all windows (initial window and zoom window) of given array, choose **File.../Close All.**

If you have closed parent window, you will not be able to see the full map again. The only way to get back is to load the file again.

To receive short information about data in the window choose **Options.../Info...** menu. Here you can see the geometrical locations of the corners of the grid and the number of columns and rows, as well as the local minimum and maximum of the data.

In some cases you can choose use MagPick for profile processing only. You must always load a grid to create the map view and see locations of profiles. You may want to create a ”dummy” grid which has following format:

```
 DUMMY
100 100
 62740 63200
 33130 33820
-9366.12 17963.5
```

1. Ujse the magic word ”DUMMY” so program can recognize the file.
2. Numbers of columns and rows of an empty grid.
3. Minimum and maximum X coordinates.
4. Minimum and maximum Y coordinates.
5. Minimum and maximum of the ”dummy” field.

It should be noted that in this case the program creates a real array (i.e allocates memory) therefore you should not choose large numbers for rows and columns.

In case of a ”dummy” grid you might find it useful to check out the **Snap to grid** option in the **Settings...** dialog box.

MagPick can create dummy grid for you internally. After you load profile information just create *grid* view with **File.../New...** menu. Program will show profile map, faking underlying map internally. There is no need for ”dummy” file in this case.

3.2 Drawing and clipping on top of the map

3.2.1 Magpick vector formats: lines, polygons, points, clip area.

Magpick allows you to plot some additional information above your magnetic field. It can be useful to navigate inside the area. Choose menu **Edit.../Drawings..**; dialog box appears which allows you to append drawing files.

Currently there are four types of information which can plotted:

1. **Lines** You should prepare a file which has a special format. Here is an example:

```
> UTM GREY 0
0 0
10 10
> UTM RED 0.1
10 10
20 0
```

Each line segment starts with the sign >; that makes file compatible with GMT system. The word ”UTM” indicates that the data is in meters, ”GEO” indicates that they are longitude and latitude. In latter case MagPick will use the UTM projection before plotting the data.

Then you can choose the color of the line from a fixed number of names:

```
AQUAMARINE, BLACK, BLUE, BLUE_VIOLET, BROWN, CADET_BLUE, CORAL,
CORNFLOWER BLUE, CYAN, DARK_GREY, DARK_GREEN, DARK_OLIVE GREEN,
DARK_ORCHID, DARK_SLATE_BLUE, DARK_SLATE_GREY DARK_TURQUOISE,
DIM_GREY, FIREBRICK, FOREST_GREEN, GOLD, GOLDENROD, GREY, GREEN,
GREEN_YELLOW, INDIAN_RED, KHAKI, LIGHT_BLUE, LIGHT_GREY,
LIGHT_STEEL_BLUE, LIME_GREEN, MAGENTA, MAROON, MEDIUM_AQUAMARINE,
MEDIUM_BLUE, MEDIUM_FOREST_GREEN, MEDIUM_GOLDENROD, MEDIUM_ORCHID,
MEDIUM_SEA_GREEN, MEDIUM_SLATE_BLUE, MEDIUM_SPRING_GREEN,
MEDIUM_TURQUOISE, MEDIUM_VIOLET_RED, MIDNIGHT_BLUE, NAVY, ORANGE,
ORANGE_RED, ORCHID, PALE_GREEN, PINK, PLUM, PURPLE, RED, SALMON,
SEA_GREEN, SIENNA, SKY_BLUE, SLATE_BLUE, SPRING_GREEN, STEEL_BLUE,
TAN, THISTLE, TURQUOISE, VIOLET, VIOLET_RED, WHEAT, WHITE, YELLOW,
YELLOW_GREEN.
```

Then you specify width of the pen. 0 means 1-pixel pen; other values show pen width in physical units of your map. The line coordinates follow. They can be as many segments as you need. A pair occupies a separate string.

2. **Points** If you choose to highlight some specific locations you use points. To plot them, prepare the file:

```
POINTS 12
UTM  5  5 10 RED  Point num 1
UTM 10 10 10 BLACK  Point num 2
```

First line of the file has a magic word - ”POINTS” and the annotation font size in points. This line should be always the same (font size can vary). Then each line describes one point. The first word could be ”UTM” or ”GEO” , X and Y coordinates (in the same system as data are) follow. The third number is the size of the mark on the screen, in pixels. Zero size produces no mark. The color name can be chosen from the set above. The rest of the string is optional text which appears near the mark. The mark itself has a shape of $\otimes$ with the hot spot in the centre.

3. **Polygons** This allows you to draw filled polygons to obscure part on the picture. The file has exactly the same format as the line file. MagPick joints first and last point of each line to make a closed polygon. Specify the color you you wish. The pen width should be zero to fill in required area only.

4. **Clip**. MagPick does not do real clipping as PostScript does. Do not confuse this type of clipping with grid clipping. Grid clipping changes the data, this feature draws a white polygon of complex shape to simulate clipping of the picture. The clip file itself has the simplest format: it’s just two columns of the numbers. The first pair of numbers should coincide with the last pair to have a closed path. The order of points is very important. The points should go *clockwise* (see figure 9).

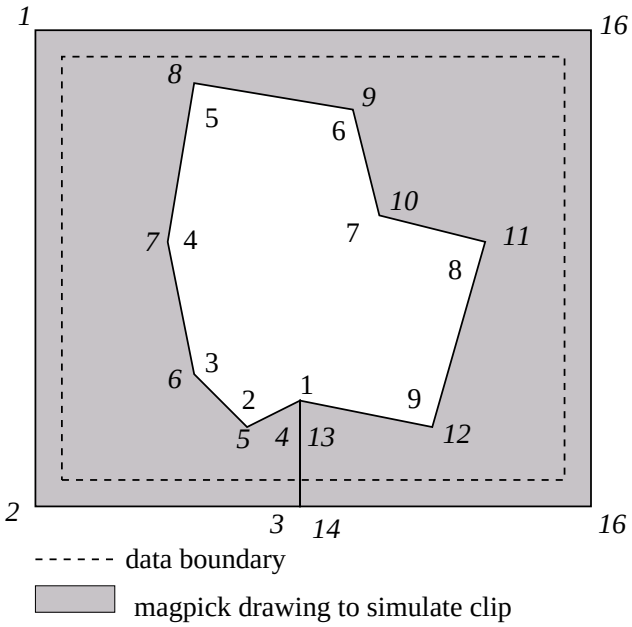

Figure 9: Clipping polygon

Here numbers *inside* the contour the show order in which *the clip path must be specified*. Note that you should start with *minimum* Y value. Italic text shows the nodes which MagPick uses to simulate clip. Shaded area is white polygon drawn to simulate the clip. Normally we assume only one clip for a map.

The order of points is not so important for screen clipping, but for postscript output it is crucial.

The order of drawings in the list is important. MagPick does drawing in the following order:

1. Color map.
2. Contours, if need.
3. Profiles, if loaded and required.
4. All drawings in the order they appear in the list. It means the clip will affect *only* graphics which are listed *before* clip itself plus the colored map and isolines.
5. Coordinate mesh and additional text (if need).

3.2.2 Bringing an AutoCAD DXF drawing into Magpick.

In many cases users can have their maps in AutoCAD(TM) format. Magpick is not capable of reading directly neither DWG nor DXF formats, however some simple steps and using third party software allows a DXF drawing to be brought into MagPick relatively simple.

To use this option the user should download DXF2XYZ program available from GuthCAD (http://www.guthcad.com.au/freestuff.htm) for free. This tool (working under MS Windows only) allows the transfer of AutoCAD DXF files into a simple form of ASCII file. Please note that the program can be used for free, but not redistributed. Also see its license for industrial usage.

The problem with this program is it can not handle AutoCAD text and ellipses. The user can give up text or use a Lisp utility to convert text into polylines inside AutoCAD. To do so XSHP.LSP lisp program can be used (available for free. You can download it for example from http://www.acad.co.uk/freesoft/fonts Note that program requires ASCII font file (TXT.SHP) in the same folder as the binary font file (TXT.SHX). If you don't have an ASCII file you can use the utility SHX2SHP which is available from the same place to produce one.

Follow standard AutoCAD instructions to load the Lisp program.Then select all text in the drawing and call XSHP. It might be slow but program will finally convert all you text into polylines (it may not convert text inside Acad blocks). Save result as DXF file.

Now start DXF2XYZ and pick your DXF file. Use next settings inside DXF2XYZ:

- Ignore Z (2D) should be checked
- Entity headers should be checked. Then press button *Specify...* and check PEN NUMBER under "Components" All other boxes (ENTITY NAME, LAYER NAME, LINETYPE NAME) should not be checked.
- Under "Data Formatting" select Move to (0), Draw to (1).

Now you can produce the XYZ file by pressing "Save" or "Save as...". Here is an example of output:

```
*70
0,95.39,125.00
1,96.06,130.00
1,95.00,131.00
```

```
1,90.00,134.35
*70
0,104.71,125.00
1,105.00,125.99
```

Here ”*70” denotes the AutoCAD pen number and strings that follow are line segments. ”0” means moving in the position with pen up, ”1” with pen down. You can use this file in MagPick directly, just select it with ”line” option.

3.2.3 Using ArcInfo(TM) shape files in magpick

If shape files are available they can be used in MagPick however a conversion is required. There is a command-line program shipped with MagPick called **shp2mpick** (or **shp2mpick.exe** under MS Windows). This program converts linear features from shape files into a MagPick ”line” file (see above). Both .shx and shp files must be placed in the same folder. Then program can be called as:

```
shp2mpick.exe shp_file color thickness GEO|UTM > output_file
```

here `shp_file` is the name of shape file (extension .shp) `color` is color name (might be RED, BLACK... see a 1 for full list), `thickness` is line width, `GEO` or `UTM` denotes coordinate system, `output_file` is a MagPick ”line” file. Note that all lines in that file have the same color.

The core for this program was provided by Sol Katz,skatz@blm.gov.

3.3 Simple picking of magnetic anomalies

3.3.1 Simple pick.

Magpick provides two basic options to select specific points on the grid. Note that these simple ”picks” have important value - they are used as initial positions for searching of magnetised spheres or lines (inversion). Picks can be saved into and loaded from a separate file.

Because the simple interpretation of magnetic filed assumes that the source is in between local minimum and maximum of the field, the pick consists of two points. There are two ways of picking:

- **Simple pick** Go to **Edit.../Simple pick** for the window where you decide picking. The mouse cursor will change its shape to +. Now move cursor to some point and click left button. A ribbon dashed line appears after pointer. Move mouse in the second point and click the left button again. A black line segment (with small crosses at the ends if need - see figure 1) is drawn on the screen. If the checkbox **Snap to grid** is checked (on), the ends of the pick are always in the centres of the grid cells. It may not allow to set pick where you want if grid has low resolution. In that case check it off.

- **Square picking** when **magpick** helps you to find local extremum. Go to **Edit... /Rectangular pick**; the mouse cursor changes its shape to reflect your choice. When *square picking* is used there are two things that must be done in the right order: first show the area where maximum is, then show where minimum is located. Point the mouse in the corner, press left button and drag. The ribbon box will show your choice. When the appropriate point is reached, release mouse. Do the same to the minimum point. MagPick will search for the maximum point in the area you showed first. Then it will find the minimum point in the area you showed second, and draw a pick between these points.

Picks can be saved into the file or loaded by **File.../Open pick...** and **File.../Save pick...**. If you try to exit the program or load new picks without saving of the previous picks a warning appears and you are given opportunity to save the job. In case you have duplicated picks in the file secondary copies are discarded during loading.

The pick file itself is an ASCII file with a simple structure. Each pick is represented by one string. Here is the format of the string:

1. 3 numbers - X, Y, and the field for end of the pick where the *maximum* value of the field is.
2. 3 numbers - X, Y, and the field for end of the pick where the *minimum* value of the field is.
3. Local azimuth to minimum (second) point from maximum (first) point plus *Field direction* value (see figure 1)
4. Horizontal distance between picks.
5. Two numbers - coordinate of the middle point of the pick.
6. One number - always 0.000 This was implemented for compatibility with some software.

In case you did a false pick you can remove it by choosing **Edit.../Delete pick** option. The cursor is changed to remind you that you are removing the pick. Move it to the centre of the pick and press left button. If you are close enough the pick disappears.

To remove all picks, use *Edit.../Delete all picks*. You will be prompted to save picks in the file; if you do not want them to be saved simply press *Cancel*.

3.3.2 Pick export

Magpick provides some tools to export picks into external formats, such as X,Y,Z (dat) file, Autocad DXF format, Atlas BNA format and in a couple of internal magpick formats to be drawn on top of a magnetic map. (See *Drawing and clipping on top of the map*). All these are available under *Files.../Export pick.*. menu. During the export to DAT, BNA and DXF pick positions can be transformed two ways:

- Linear transformation along X,Y axis can be applied. This includes scaling and offset.
- Inverse UTM transformation can be applied. (see Universal Transverse Mercator / Gauss Kruger in MagPick). This result can be presented in geodetical latitude and longitude, while MagPick works with Northing and Easting.

Figure 10 shows sequence of dialog boxes for exporting dat files. It is important to check if the UTM transformation is used; it may be not what you want to keep old and exported data in the same coordinate system. Option *Degrees and minutes* and *Degrees, min and sec* makes sense only if your data was loaded in MagPick using Lat/Lon (not recommended) or you do inverse UTM transformation on the output. In addition to UTM transform you can apply a simple linear scaling and shift.

Exporting DXF and BNA formats are similar, except you have less choice in what you can export. You can export end or middle points, or picks as line segments, or both.

Please note that the results of a DAT, DXF, and BNA export are not loadable back to **Magpick**.

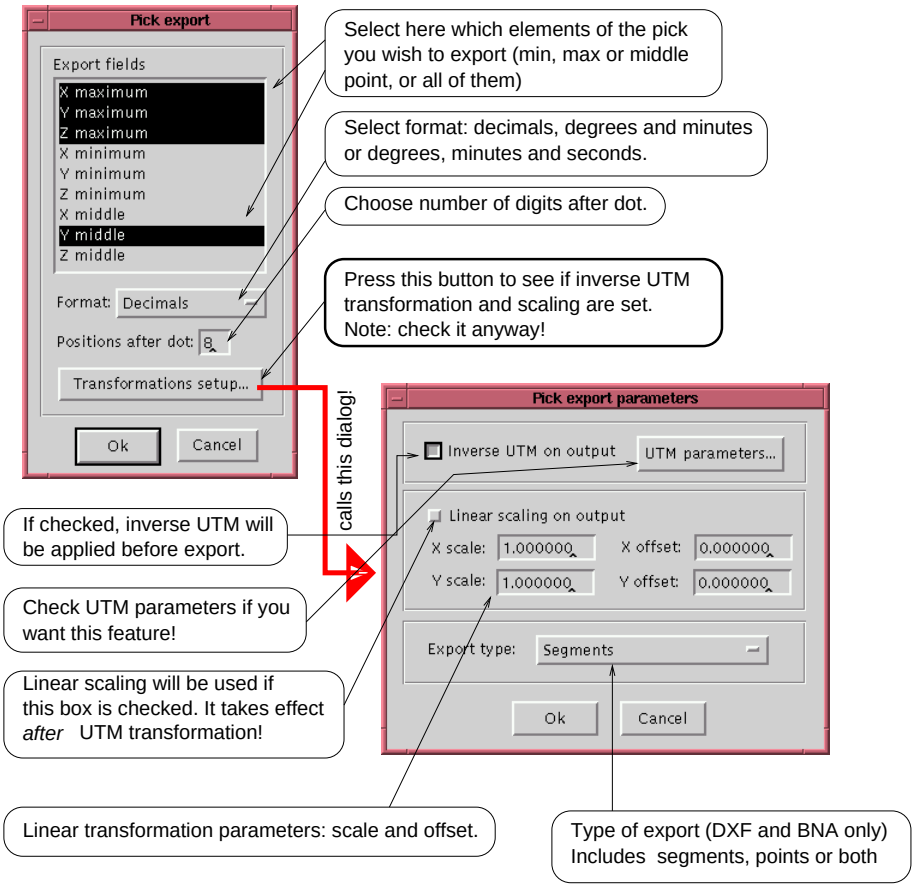
Pick export
Export fields
X maximum
Y maximum
Z maximum
X minimum
Y minimum
Z minimum
X middle
Y middle
Z middle
Format: Decimals
Positions after dot: 8
Transformations setup...
Ok
Cancel
Select here which elements of the pick you wish to export (min, max or middle point, or all of them)
Select format: decimals, degrees and minutes or degrees, minutes and seconds.
Choose number of digits after dot.
Press this button to see if inverse UTM transformation and scaling are set. Note: check it anyway!
calls this dialog!
Pick export parameters
Inverse UTM on output
UTM parameters...
Linear scaling on output
X scale: 1.000000
X offset: 0.000000
Y scale: 1.000000
Y offset: 0.000000
Export type: Segments
Ok
Cancel
If checked, inverse UTM will be applied before export.
Check UTM parameters if you want this feature!
Linear scaling will be used if this box is checked. It takes effect after UTM transformation!
Linear transformation parameters: scale and offset.
Type of export (DXF and BNA only) Includes segments, points or both

Figure 10: Export picks as DAT file.

Export results can be loaded into MagPick if you export them as *Magpick points* or *Magpick lines*. These represent the internal MagPick format for additional drawings on top of a magnetic map. In the first case, middle of the picks gets exported, in the second case picks as lines. You can choose the color and size of annotation for these elements.

3.4 Automatic pick

Besides manual anomaly selection MagPick has a tool for automatic finding of pair maximum - minimum. This feature is experimental and will be improved in future. Presently is is available under *Edit / Auto pick*. The selection algorithm is fairly simple and uses the following steps:

1. Find all points which are local minimums and maximums.
2. Create pairs maximum - minimum. The number of these pairs can be fairly large: each maximum can be matched with each minimum. To reduce number of possible pairs the following user-defined restrictions apply (see figure 11):
   - Two points can be treated as a pair if the distance between them is in the user-defined range.
   - Two points can be treated as a pair if the field difference between is in the user-defined range.

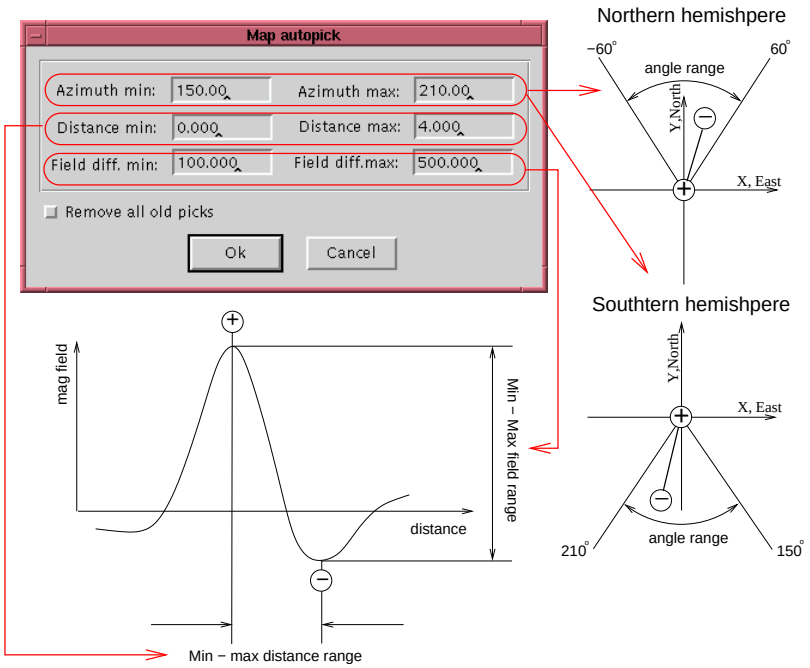

Figure 11: Setting parameters for automatic anomaly selection (picking)

- Two points can be treated as a pair if the azimuth from maximum to minimum is in the user-defined range. For example, in northern hemisphere anomalies should have minimums located north from maximum; therefore the azimuth range should permit only this selection.
- A pair is accepted if its field value in the middle point is in between the end values.

Note that still after all these limits one point can participate in the different pairs. To resolve ambiguity pairs are sorted in accordance of difference between their maximum and minimum fields. The sorted list is scanned to create unique pairs.

To use this feature go to *Edit / Auto pick*; select angle, distance and field ranges; if you want to remove all existing picks (made by hand or results of previous auto pick) check *Remove all old picks*; Press Ok. Depening on size of the map and its complexity the operation will take different times to complete. If you checked *Remove all old picks* you are prompted to save old picks before MagPick removes them. As a result you get many anomalies selected.

It is recommend that you inspect results before going to magnetic source estimation (it also can be done automatically for all anomalies by *Inverse / Run batch...*). Magpick may place some picks incorrectly, and you should correct them.

3.5 Profile information loading and viewing

3.5.1 Profile loading.

Besides map processing MagPick allows loading of the profile data. The input can be any ASCII file(s) which has column organisation. At a minimum the file should have three columns - X, Y

(coordinates of the point) and a value of the magnetic field. To make loading and processing faster, the data can be decimated during reading.

To enable profile features you have to prepare a special file with file names and column numbers or use the *Easy profile load* feature. The latter greatly simplifies access to profile information but has limited application (for example, each file can have only one data set; if you need several data sets then you need to read the file two or more times.) What you use for profile loding depends on the format of your data and your expirience with a computer. For example people with little expirience using Unix tools and with a task to process thousands of profile lines (not unusual case with marine magnetic surveys) may find it easier to write a simple script. This would create a MagPick *profile list file*. Users familiar with Microsoft Excel should assemble such a list manually. Aslo all Unix tools are available under MS systems nowdays for free.

Probably one of the ways might be loading a few lines with *Easy profile load* and saving them as a profile list. Such a list can be used then as a template. This manual starts with a descpiption of the profile list file format (hard part). Users who want it fast can read *Easy profile load* 3.5.2

Each line of the file consists of description of information loaded from one data file. Description fields are separated with one or more spaces. Here is the format of the line:

1. It may contain or may not words ”SPLIT=NN”. Here is ”SPLIT=” (all capital letters) key which indicates that data set has to be split into lines. ”NN” could be an integer number (without ”.”) or real number (with ”.”) In first case it is treated as column in the file which has line number. Any character string can serve as a line number; MagPick assumes that the new line starts when a string changes. In the second case (with ”.”) the value is treated as a distance between adjusted points to break data into separate lines. If the distance between points is more than the current value new than a line starts. Note that this field is optional.

2. It may or may not contain the words ”XFALSE=NN1” and ”YFALSE=NN2” Values NN1 and NN2 are false Northing and Easting: values to be *added* to X, Y coordinates in the file. Note that they must be negative if you want to reduce for example full UTM coordinates to short ones. This is a particular useful feature if the data is presented in full UTM format. To decrease overhead MagPick uses floats (4 byte words) to store all values. Therefore loss of accuracy for full UTM coordinates is possible. Use false Northing and Easting to avoid this loss. Note that these field are also optional.

3. Name of the profile file (with a path, if it is not in the current directory).

4. Color name for plotting inactive profiles on top of magnetic map.

5. Color name for active profiles.

6. Number of data sets in the current file. One file can contain more than one profile (for a multi-array magnetometer system, for instance).

7. Decimation. While reading, the program can take only part of the data (each 10th sample, for instance). It increases the speed of loading and all subsequent operations. In most cases decimated data still has enough resolution to represent geometrical position of profiles and field graphs. If then one decided to load all points, it is possible to accomplish it inside MagPick.

8. Sequences of four numbers - X,Y,Z, T for each data set. Thus the total number will be *the number of data sets* $\times$ *4*. The Z axis goes down as normal in geophysics. In case you do not

have Z in the file you can specify a constant value by typing expression **h=value** instead of number of Z column. Here *value* is desired Z.

9. Next information is optional and reflects features of an off-shore magnetometer array. It allows you to calculate the GPS heights of the sensors if GPS hight of antenna and depth of the array are known. To take advantage of this feature print ”A” at the end of the string, and then troughout the space column number in the data file where the GPS hight is, and then the antenna hight above sea level (in meters). If MagPick finds an ”A” it uses the following expression for Z coordinates for all datasets:

$$z = h_{gps} - h_{antenna} - \frac{1}{N}\sum_{i=0}^{N} z_i$$

Where N is number of sets. This expression recalculates all elevations into the geodetic system. Then MagPick changes sign to reflect downward direction of Z.

Here is an example of such a file:

data_23_09_97/mag_p02_23_09_97_filt.dat BLUE RED 4 20 27 28 3 1 29 30 7 5 31 32 11 9 33 34 14 12 A 44 5.2
data_23_09_97/mag_p03_23_09_97_filt.dat BLUE RED 4 20 27 28 3 1 29 30 7 5 31 32 11 9 33 34 14 12 A 44 5.2
data_23_09_97/mag_p04_23_09_97_filt.dat BLUE RED 4 20 27 28 3 1 29 30 7 5 31 32 11 9 33 34 14 12 A 44 5.2
data_23_09_97/mag_p05_23_09_97_filt.dat BLUE RED 4 20 27 28 3 1 29 30 7 5 31 32 11 9 33 34 14 12 A 44 5.2

While loading progress indicator appears on the screen. You can stop loading, if you want. When it finishes, the total number of loaded profiles is shown.

It is possible to have a slightly different format when you need to load several profiles from one data file. Here the first column can have the following format: #number1_number2. Here number1 is the string number where profile data starts and number2 is the string number where data profile ends. Here is an example of such a file:

```
#1_74       dat/b1_east.dat BLUE RED 1 1 1 2 h=0. 3
#75_151     dat/b1_east.dat BLUE RED 1 1 1 2 h=0. 3
#152_228    dat/b1_east.dat BLUE RED 1 1 1 2 h=0. 3
#229_304    dat/b1_east.dat BLUE RED 1 1 1 2 h=0. 3
#305_379    dat/b1_east.dat BLUE RED 1 1 1 2 h=0. 3
#380_454    dat/b1_east.dat BLUE RED 1 1 1 2 h=0. 3
```

3.5.2 Easy profile load.

Having described *profile list file* in detail now we present a quick way to load profile data file with a column structure. Here is a step by step description what to do.

- Go to *File / Profiles / Simple load*.
- Dialog box 12 appears on the screen. Enter *False Easting* and *False Northing before* picking any data files (you also can use individual values for different data files). Note that the usage of false Northing and Easting is recommended in the case of full UTM coordinates (if they are not truncated to the short form, otherwise loss of accuracy will occur).
- Press *Add* button and then pick the data file. The bottom part of picture 12 appears.

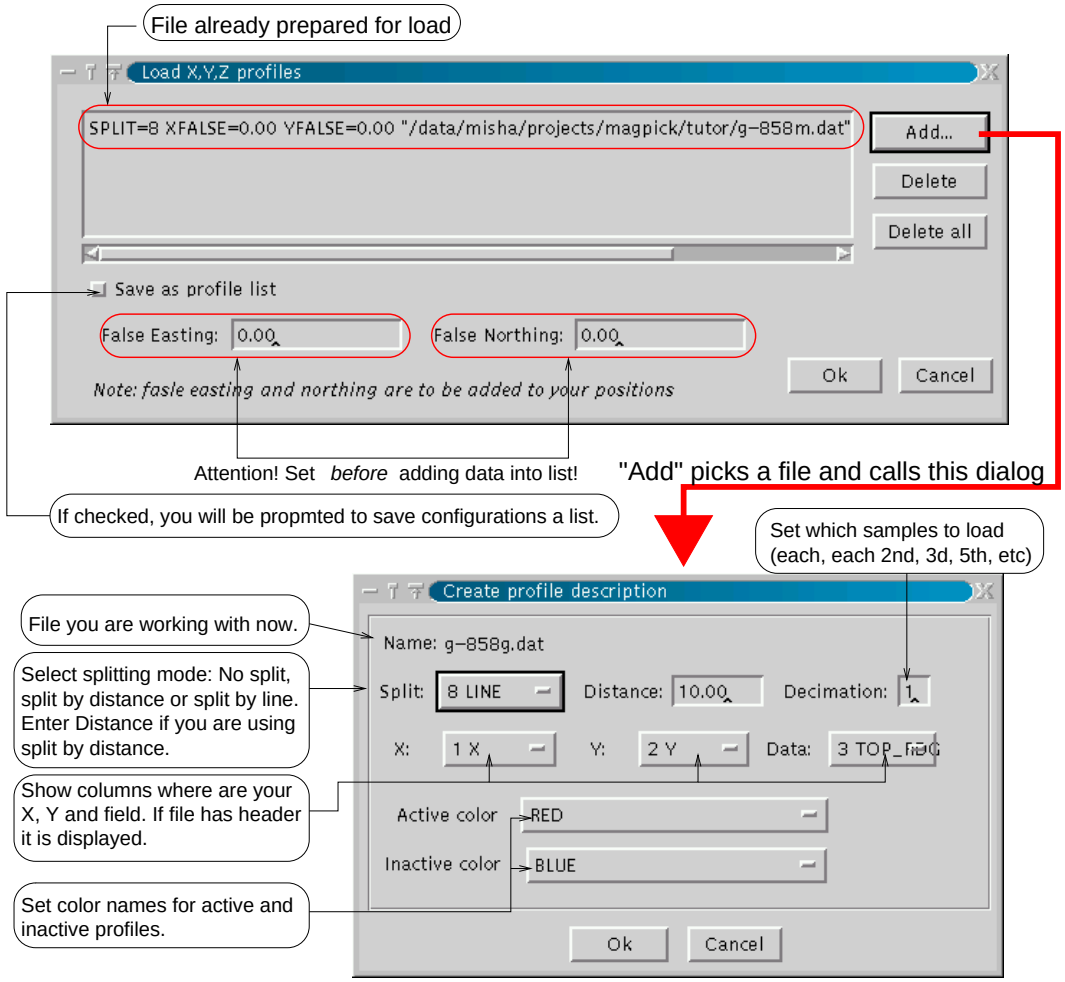
File already prepared for load
Load X,Y,Z profiles
SPLIT=8 XFALSE=0.00 YFALSE=0.00 "/data/misha/projects/magpick/tutor/g-858m.dat"
Add...
Delete
Delete all
Save as profile list
False Easting: 0.00
False Northing: 0.00
Note: fasle easting and northing are to be added to your positions
Ok
Cancel
Attention! Set before adding data into list!
"Add" picks a file and calls this dialog
If checked, you will be propmted to save configurations a list.
Set which samples to load (each, each 2nd, 3d, 5th, etc)
Create profile description
File you are working with now.
Name: g-858g.dat
Select splitting mode: No split, split by distance or split by line. Enter Distance if you are using split by distance.
Split: 8 LINE
Distance: 10.00
Decimation: 1
X: 1 X
Y: 2 Y
Data: 3 TOP_RED
Show columns where are your X, Y and field. If file has header it is displayed.
Active color
RED
Inactive color
BLUE
Set color names for active and inactive profiles.
Ok
Cancel

Figure 12: Easy profile loading

- Set the method to split into lines, or *No split* if entire file represents just one line. If you choose *Distance* then a new line is started when the distance between two points is more than this value. If you choose any file columns than it will be used as a line indicator. If the string in that column changes, a new line is started. Enter the *Distance* value if you are splitting data by distance.

- Enter *Decimation*. This would allow to load just only part of the data. For example, if *decimation* is equal 2, only each second point gets loaded. Note that you can get all points later within MagPick (increase the resolution).

- Show which columns hold X, Y positions and field. If file has a header its fields displayed. If not, just only the column numbers.

- Pick colors for active and inactive state of profile. Press OK to accept.

- A new strings appears in the list, which tells MagPick how to treat this file. Use *Add* button to add as many files as you want. Note that you can pick the same file but with different columns.

- After you picked all data files you can check *Save as profile list*. You will be prompted to save

result of your work as *profile list file*. It means when you need to load this information next time you just pick this file directly (menu *File / Profiles / Load list*) without going through all these steps again.

- After processing of all the profiles the program reports how many profile lines you have. If some profile data has been loaded already it asks would you like to erase it from the memory or just append new data. You may be requested to close some profile views if you have them on the screen.

If after profile loading go to *File / New* you have a choice: make profile or map view. In the case of map view MagPick will create a dummy grid to display positions of your profiles. If you only need the stack plot then you don't need to perform any other actions.

To prepare (interpolate) grid data go to *Profiles / Interpolate* and pick a method. New map window created automatically (see 4.1)

3.5.3 Operation with profiles on the map.

After loading, a new object appears in the program - "list of the profiles". This enables plotting of geometrical positions on the maps (if this feature is enabled - see figure 1), viewing of the profile data as linear graphs and allows putting marks on them. Each profile can be in an active and inactive state. This is shown by color. An active profile is shown in the profile view window (if any) and highlighted on the map. When you choose **New...** in any window a small dialog box appears which allows choosing the type of view you want. Depending on where you choose **New...** (in map window or in root window of the program) there will be two or three choices. They are:

- **Grid view** Create a normal window for map displaying. That is the same as without profile loading. If profile data is loaded at time map created, MagPick creates a fake empty grid to allow viewing of their positions.

- **Profile view.** This allows to see profiles as linear graphs one by one. There are four possible types of presentation: as T(X), T(Y), T(d), T(p). Where X and Y is local coordinates, d - distance along profile (always starting from zero) and p - projection on user-defined axis. The last type of graph is possible when the profile view is opened from map view window with plotted direction of a new axis. If there are several data sets in one profile file they are shown by curves of different colors. All profile view windows share the same data (global list of profiles). When you are working with one window the results can appear on all the map windows.

- **All profiles in the window (Profile inversion).** Show all profiles which cross the parent map window in the limits of the window. The same types of presentation are possible. Opposite to profile view, program does a local copies of profiles and makes all profiles active. This means that they can be viewed simultaneously on the same coordinate axis. As its name implies, this type of view provides an inversion. You can have *only* one profile inversion window opened for each map window. Operations with the global profile list will not be reflected on it.

After profile loading the bottom items of the **Edit...** menu of map view become available. They allow basic operations:

- **Direction.** Create a local axis on map view. Show the beginning of the axis, click left mouse button, show direction and click again. An arrow is drawn on the screen. Then you create a profile inversion view window, you are able to view profiles projected on this axis. You can dynamically alter the profile view by pointing new axis.

- **Pick profile.** Making profile active (inactive). Show the profile and click the left button. If mouse pointer is close enough to the profile line, profile is highlighted and profile views (if any) updated. [4]. If a map window has a child profile inversion window, this action reflects only on the child. If the profile was currently active, it becomes inactive, and vise versa. In the case when the map window does not have a child window the profile you pick becomes active and the current active profile is deactivated. In that last case the program operates with a global list of profiles, in the first case it operates with a local copy of part of the list.

- **Set marker** Put a special mark on active profile. There are two kinds of the marks (see figure 13), and they can be two marks of any kind only. When you click first time, marker 1 appears. When you do it second time, marker 2. Third time you click marker 1 is removed from its location and set in the new place, and so on. Any marker is set in *the nearest profile sample* and appears on the both views (profile and map view). Thus the location of specific points can be easily found.

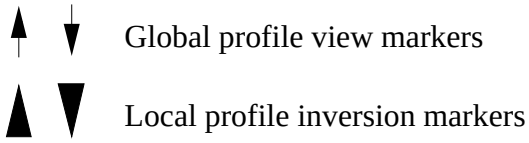

Figure 13: Profile markers

3.5.4 Parameters of the profile view.

Profile view and profile inversion view have menus types different from the map view. The most complicated item is **Parameters.../Settings...** When you invoke **Parameters.../Settings...** dialog box shown on figure 14 appears on the screen.

You you can specify all necessary information to make the most convenient view of profile information. It is important to understand, that profile view can work in two modes:

1. **Shrink to canvas.** In this mode the drawing area has a fixed size, and the profile is scaled in accordance of the minimum and maximum of the data. It means that the profiles of a different length and amplitude will always occupy the same area on the screen. It is difficult to compare them, but you see all the features of each profile. This mode is recommended for zooming because you always can easily undo it.

2. **Fixed scale.** Here scales (i.e how many pixels per nT in the vertical direction and how pixels per meter in the horizontal direction) are fixed and size of canvas is adjusted to these scales. This way you see all the profiles with the same resolution and you are able to feel space and field span. In some cases (if you set your scales for a short profile and then load a long one) it can lead to a noticeable memory consumption. This mode is not recommended if you zoom profiles. Zoom automatically changes scales and limits, therefore when you undo zoom it can create a very large picture.

Following is a full explanation of all the controls for the ”Profile view parameters” dialog box.

[4] For large profile sets some time can be needed to find profile you pick.

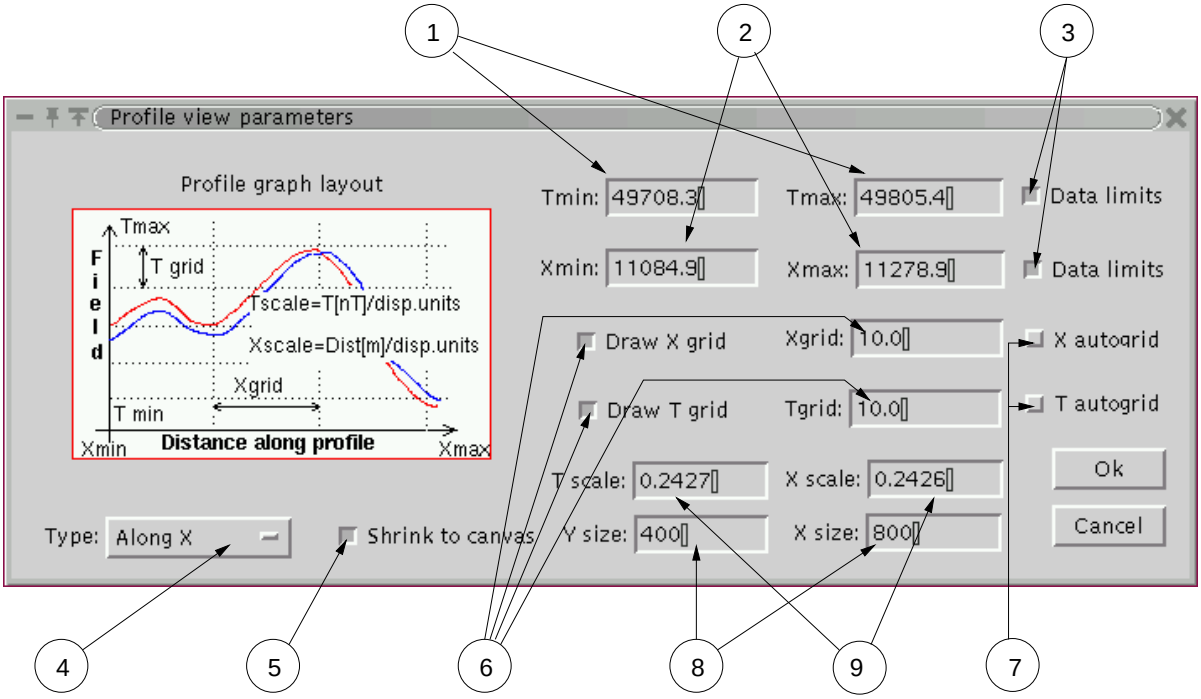

Figure 14: Profile view parameters

1. **Field limits.** Top and bottom of the view, in nT. If **3** is checked, program automatically chooses these values based on the data.

2. **Horizontal axis limits**. Left and right limits of the view, in m. If **3** is checked, program automatically chooses these values based on data. Because X axis can represent different variables (i.e X, Y, distance along profile, projection) be careful in choosing them. When you change the type of axis box **3** is automatically checked and new limits appear.

3. **Data limits**. If these checkboxes are checked data limits always will be taken.

4. **Type of X-axis**. Depending on where you created profile view there are two to four choices here.

   (a) **X,Y** profile inversion view created from map view without additional axis.

   (b) **Along profile, X,Y** profile view created from map view without additional axis.

   (c) **Along profile, X,Y, Along pointer** profile view created from map view with additional axis. In this case the direction of axis is fixed after creation of profile view; even you have changed it on the map view, profile view will still operate with an old one. This happens because the profile view is actually an independed window (opposite to profile inversion view) .

   (d) **X,Y, Along pointer** the profile inversion view which is a child of the map view with an additional axis (direction). In this case if you change the pointer direction the profile graphs are updated automatically.

5. **Shrink to canvas**. It sets the method to shrink to canvas (see above). If this is on, then the fields in **8** are unaccessible, if not checked then the fields in **7** are inactive.

6. **Grids**. Here you can specify the coordinate meshes. Check *Draw X grid* and *Draw Y grid* and enter steps for the grids. Alternatively you can check *X autogrid* and *Y autogrid* to let MagPick select the steps.

7. **Canvas size.** If **5** is on, the picture always fits in the specified size (in pixels). If **5** is off, size is chosen automatically to satisfy scale factors.

8. **Scales.** Scales for coordinates in physical units per display units (pixels). Adjust to find a value that works best. If **5** is on, the program sets these values automatically. This may be the best way to get initial values.

   It could be good initial values to start with.

Next important menu item is **File/Browse...**. If this item has been chosen the modaless dialog box pops on the screen. In this box you can choose any profile from the list you wish to see. As soon as you click the mouse the picture is updated. The active profile is highlighted on the map view as well. You can navigate to the next or previous profile by using the using the buttons marked $<<$ and $>>$. If you want to see only part of the multi set data, click on **SubSet...** A dialog box appears for you to disable or enable plotting of the specific sensor.

It should be noted that **Profile Browser** dialog box has a different functionality in profile view and profile inversion view windows. In profile view it is just a simple chooser. You can see only one profile at once. Accordingly only one line can be selected in the listbox. Profile inversion view has more functionality: you can select all or none of the profiles crossing the parent map window, and you can select subsets in these profiles. Only graphs plotted on the profile inversion view window are used for inversion. A good practice is to change profile decimation before the inversion (if there was any decimation during initial load). Each point should be loaded. This task can be accomplished by the **Resolution...** button.

The profile view window allows same basic operation with a mouse. All these facilities are available under menu **Edit...**:

- **Set marker** Put a mark on the given line. Move the mouse to the place and click left button. A mark appears on the screen (for the type of mark see figure 13). Markers can be set on curves only and only at the data node. The program chooses the nearest node and places the mark. If decimation is large the actual mark position and the mouse position can differ considerably.

- **Zoom**. You can zoom part of the window in the same way as for map views, but the zoomed part replaces the content of the view. This can be done several times. If you work in **Shrink to canvas** mode, then you can return to the state before zooming just by calling **Settings...** and pressing Ok (or use **Redraw**). In case you are in the scale mode it is more tricky. You should set scale factors back as they were before zooming .

- **Remove** This item is present only in the profile inversion view. In case you have too many profiles on your screen you may deactivate them interactively (and therefore deselect them in the **Profile Browser** list). This way you remove *all* subsets from the screen. To remove just only part of them use **Profile Browser** dialog.

3.6 Printing.

MagPick has printing facilities which are implemented thought the **Preview...** menu for all types of views. To make a printout, simply open **Preview...**. A separate window with a page pops on the

screen and you can see a preliminary plot. This view is not exactly the same you will get on paper. To make sure, print it to the postscript file and view it with Ghostscript. Note that MagPick always scales the plot to fit the given paper size.

In **Print setup** dialog box you are able to choose the printer, file, paper type, and portrait or landscape mode. Landscape mode is not shown in the preview, but the printout is correct.

Each view window has the menu **Title...** where you can set some additional features of the plot such as axis annotations, common plot header, and font size. All these items have default values if you do not call **Title...** for given window.

Caveat: If you are printing to the file, you may encounter a problem. When you open **Preview...** the second time, your first postscript file is truncated to about 100 bytes. To avoid this, change name of the file if you want to keep this file before you call **Preview...** again.

4 Grid operations.

Magpick allows you to create and modify grid data loaded in a variety of ways which are available under *Operations...* These features are under development and will be extended in the future.

4.1 Making grid out of profile data.

After the profile data has been loaded a regular grid (map) can be created. There are two methods available: gridding with tension by [3] or by triangulation with linear interpolation [4].

There are a few places where gridding procedure can be started. Originally it was located in profile view under *Files / Interpolate grid* but because of obscurity it also available under map view *Profiles / Interpolate grid*. Here is a basic sequence of operations to make and view a grid.

- Start MagPick and load profile data. Use the profile list or *Easy profile load* (see 3.5.2). Note that you can load few profile lists (or use easy load few times) by appending new profile data to dat tat is already loaded. After you complete this operation MagPick maintains the profile data internally.
- If your primary goal is to make a map, go to *Profiles / Interpolate grid* and pick the interpolation method you prefer *Spline* or *Triangulate*.
- Fill in the interpolation parameters and start interpolation.
- After interpolation completed, **Magpick** will save the map into a file and automatically load the newly calculated map into current map view, or create new view if interpolation has been started from main menu.
- Adjust the view parameters.
- If you want first see the profile locations and possibly a stack profile plot, go first to *File / New* and pick *Grid view*. The program will create an empty (fake) grid just to have a base to display profiles. You can start interpolation from that window also.
- If you want to examine profile data and possibly modify it go to *File / New* and pick *Profile view*. Adjust the orientation (along X or Y axis; in the case of data collected with ”Geometrics” G-858 magnetmeter you should choose Y). You also can start the interpolation from the profile

view under *File / Interpolate grid*. However a new grid won't be automatically loaded if you start interpolation here.

Keep in mind that there is no need to save the interpolated grid because it has been saved already. However you might do it if you did some transformations or simply want to change the grid file format.

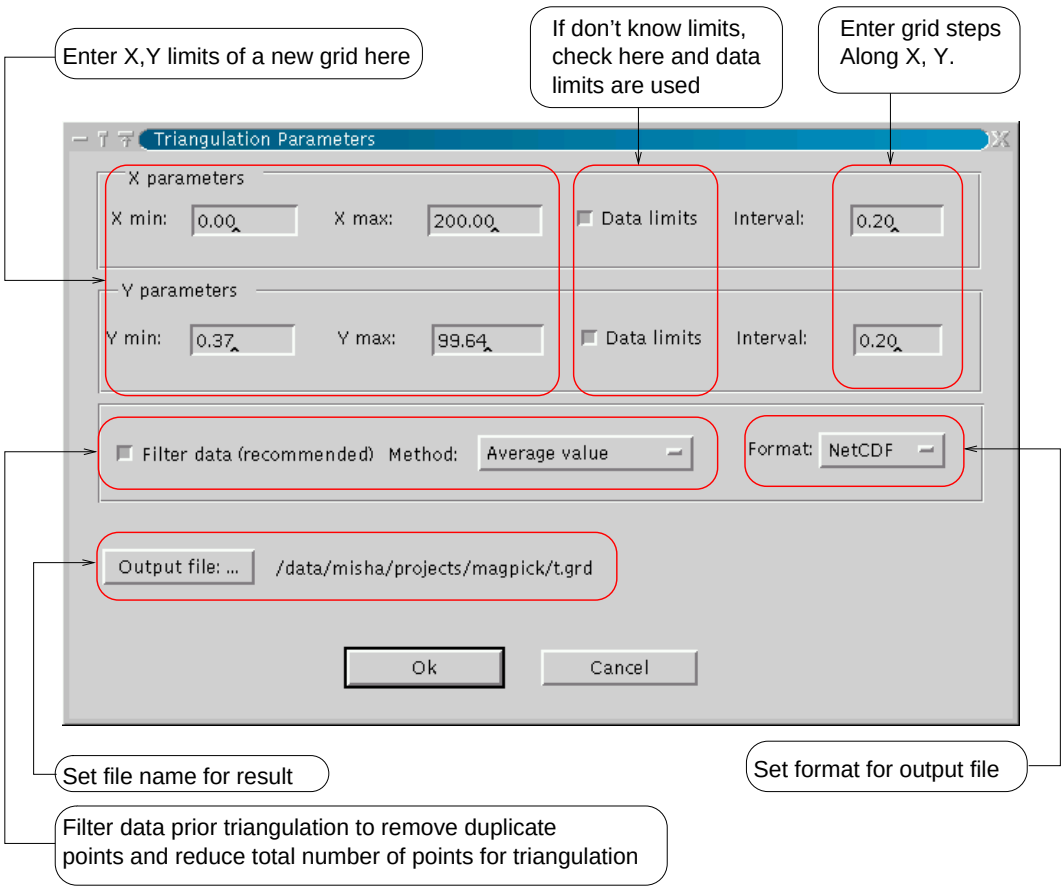

Figure 15: Gridding profile data with triangulation

4.1.1 Triangulation with linear interpolation

One of the primary methods employed by MagPick to interpolate a map from scattered points (profile data) is triangulation that follows by linear interpolation inside triangles. MagPick uses the method described in [4] to build a Delauney triangulation network. Then each triangle is used to find interpolated field values into regular grid cells.

This method works well in case of relatively uniform distribution of data points. However results may not look good if there are only a few profile lines separated by considerable distance. Also note that grid nodes outside the triangulation network do not get any field value attached. Thus the method provides some natural ”clipping” of the data.

Potential problems arise when data set has duplicate data points or points too close to each other. Triangulation may fail or the program even crush in that case. Because of that it is recommended to process data with a filter before building a triangulation network.

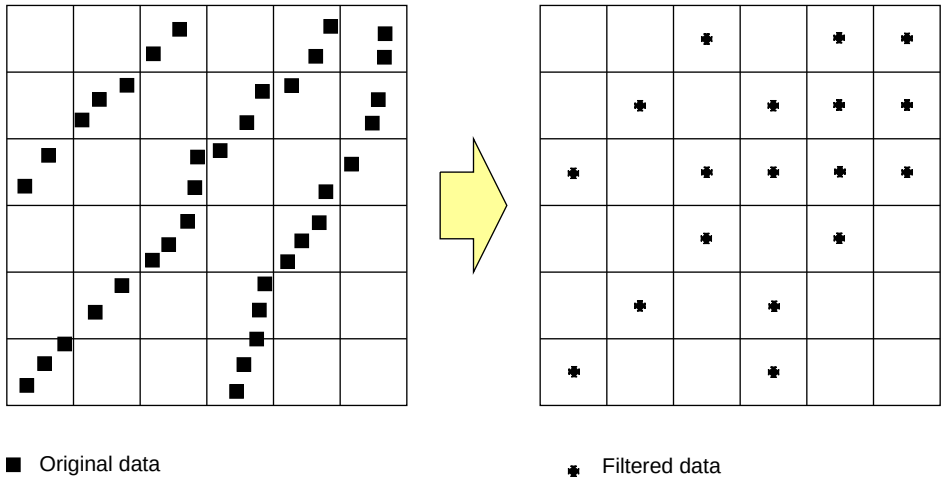

Figure 16: Illustration of data filtering. Squares represent original data and circles the result of filtering. All data points inside one grid cell are replaced with one point

Refer to figure 16 to understand how data filtering works. It affects data points inside one grid cell of a new map. All these points are replaced with one point located in the middle of the cell. The following are options for data value:

- Simple average of all data points inside cell is calculated and assigned to the middle of the cell.
- Median value of all data points inside cell is calculated and assigned to the middle of the cell. This might be better when data has considerable spikes.
- Point nearest to the middle of the cell is taken, other points inside the cell are ignored.

This procedure greatly reduces amount of data being triangulated. Note that this idea is similar to the **blockmean** program from GMT package ([3]).

4.1.2 Gridding with splines.

This feature employs a method developed by Smith and Wessel[3] which is an enhanced modification of the minimum curvature algorithm. It allows the user to control interpolation using the *tension* parameter ranging between 0 and 1. Tension set to zero gives a pure minimum curvature solution which can have undesirable oscillations. Tension set to one delivers a harmonic solution - no maximum and minimum except data points. Tension equal 0.25 is used to reduce oscillations and generally recommended for potential fields such as gravity or magnetic, The value of 0.35 is for steep topographic data.

The method also allows the user to constrain a solution with fixed values (interpolated data points can not be out of pre-defined range) or with data minimum and maximum values. An unconstrained solution is also possible.

The method is iterative and *convergence limit* and *total number of iterations* can be entered. The program stops iterations when the maximum absolute change in any grid node is less than the *convergence limit*. The program also will stop if the *total number of iterations* is exceeded.

4.2 Save grid.

There is no need to save a grid created by MagPick because it gets saved during its creation. However MagPick provides a set of operations on existing grids. After each operation has been used the result should be saved into a file.

First, if you wish to keep any change you did with a grid you should save it. Go to *File / Save...* and pick the file name you want to use. Then MagPick asks about the format for the grid file. There are three possible formats:

- SURFER ASCII This is an ASCII grid format from Golden Software. It is compatible with SURFER and machine-independent (because it is ASCII).
- SURFER BINARY The same as above, but binary. It is NOT machine independent (little endian and big endian computers becomes incompatible if you use this format to exchange data). It corresponds to SURFER binary grid format up to version 6.
- NetCDF This is binary format based on NetCDF library. It is machine-independent and compatible with GMT system [3].

All these formats can be read and written by MagPick.Therefore if you are using only MagPick and only a certain type of computer it is not important which format you use. Regarding space, SURFER ASCII wastes maximum, and NetCDF minimum.

After you have selected the format MagPick saves the grid file.

4.3 Create clip path.

This function allows you to create a file which can be used as a clip to trim the picture on the screen. No grid modification is involved, and therefore no grid saving is necessary. The sequence of operation is next:

- Go to *Edit / Polygon*. Mouse changes its shape to the pen. Draw the polygon. The left mouse button adds a node to the polygon, the right button removes latest node. To close polygon hit its first point. To draw a new polygon, go to *Edit / Polygon* one more time (existing polygon will be erased).
- Go to *Operations / Save clip*. Pick the file name you want. Press OK.
- After the file has been saved, go to *Options / Drawings* and press button *Add...* Choose file the type *Clip*. Pick the file you have just created. Press Ok, and press Ok once more to close the dialog.
- To reflect clip, redraw the picture *Edit / Redraw*.

Please note that *Additional drawings...* list is not saved when you exit MagPick. Therefore you should load the clip file again when you start MagPick next time.

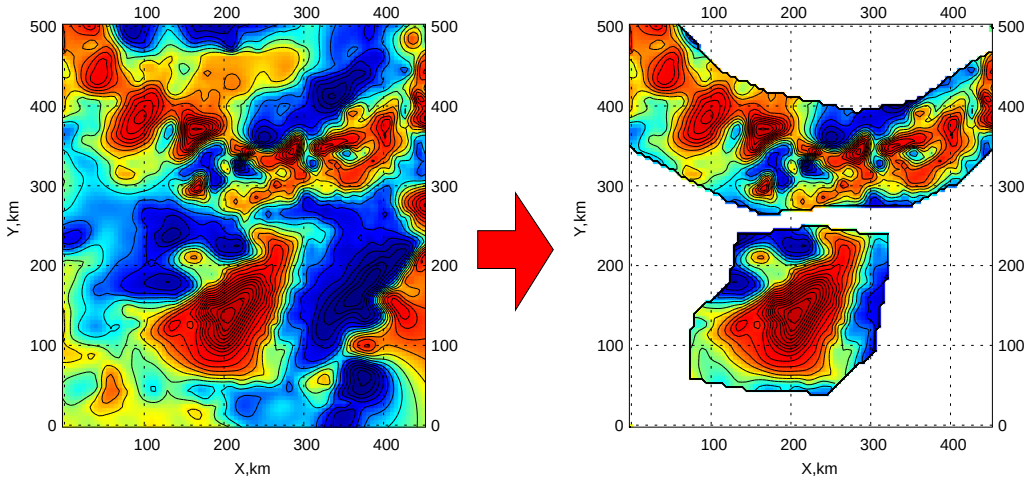

Figure 17: Result of grid clipping: Draw polygon, then go to *Operations / Clip grid*

4.4 Clip the grid.

Clipping the grid does not create an additional file. If you are doing clipping in the zoom window, the area you see in this window is affected. Therefore you must save the grid file if you want to use it in the future. The following is the procedure to do a real grid clipping.

Operations is next:

- Go to *Edit / Polygon*. The mouse changes its shape to the pen. Draw a polygon. the left button adds a node to the polygon, the right button removes latest node. To close the polygon click on its first point. To draw a new polygon, go to *Edit / Polygon* one more time (existing polygon will be erased).
- Go to *Operations / Clip grid.* Choose the part you want to be blank (inside or outside polygon). Press OK.
- The program clips the grid in the current window and in the all windows which share the same data array. MagPick redraws picture automatically.

Please note that there is no Undo operation. This means you should be careful and probably save the grid also before clipping. The clipping result is displayed on figure 17

To blank the data magpick uses the value 1.70141e38 in MS Windows version and 1.e35 in the Unix version.

5 Profile data transformations.

This section describes the MagPick features which allow to modify loaded profile data. It includes the following:

1. Saving profile data. Certainly profiles must be saved if any transformation has been used. Note that new profile list (or *Simple load* menu call) might be necessary in order to load saved data into program next time.

2. You can save only the only profile parts inside the polygon. This allows to cut unnecessary sections of the data to be removed.

3. Profile cutting. These operations can be used to remove part of the active profile. It is based on user marks.

4. Profile data smoothing. A simple cubic spline can be used to smooth data (magnetic field) along the profile.

5. Profile position shifts. Any (or all) profiles can be shifted with constant offsets along X and Y axis.

6. Profile position smoothing. Any (or all) profile positions can be smoothed with some type of cubic spline.

7. Profile position recalculations based on the profile direction. This includes position shift along and perpendicular to the track. Dragging recalculations can be used for repositioning. It is simple simulation of the object being towed behind the vessel.

There are some note worthy facts about the way profile data is handled in MagPick.

- All data is stored as floating numbers (4 bytes). This may lead to loss of accuracy if you are operating with large numbers. Typical examples are full UTM coordinates or a full magnetic field while looking for anomalies less then 0.05 nT. In the magnetic field this is negligible, but you could note difference after saving data with MagPick. It is not recommended to use full UTM; use false northing and easting to reduce the accuracy requirement.

- There are two profile views in MagPick. One is simple *Profile view* where you can see one profile at a time. This kind of view operates with the common profile list. Therefore changes of this view could be seen on each other view. If you do *All profiles in the window* from the map view (*Profile inversion* in older magpick versions) MagPick duplicates all profiles which are inside current map view. Note that only one *All profiles in the window* can be opened at a time for one map view. When you close this window the data is *not copied* back into the main profile list. Therefore you should save profiles before closing this window if you did modify them. MagPick will usually warn you about it.

- Profile operations can affect profile views and the map views. For example if you cut part between marks using the profile view, you need to update (redraw) map view by calling *Redraw* function.

- Also you should know that the profile data can be loaded with a different resolution (decimation). For example, only each 5th data point could be loaded. Any transformation you do in MagPick affects only the loaded points, not all the points in the original file.

5.1 Saving and re-loading profile data.

Profile data can be saved by calling *File / Save* menu item in the profile views or by calling *File / Profiles / Save* in the map views. Remember that if *Profile inversion* or *All profiles in the window* is used the operation will be applied *only* to the profiles in current view. After the menu item is called, a user should choose name of the file to save the data. The next dialog appears on the screen and gives the following choices:

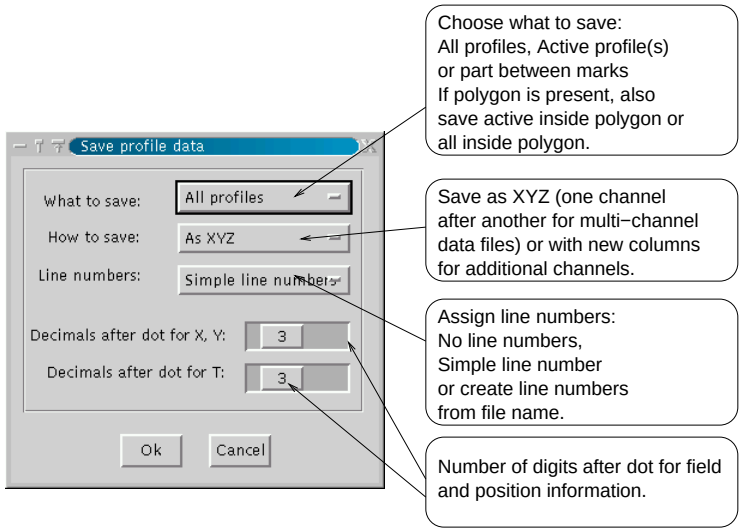

Figure 18: Save profile parameters dialog

- *Save all profiles*. This means that profile data is saved. If you are operating with the global profile list all loaded data is saved. If you are working with *All profiles in the window (profile inversion)* view then only profiles crossing parent map window are saved.
- *Save active profiles*. Only active (highlighted) profiles get saved. When working with a global profile list, only one profile can be active at a time. *All profiles in the window* allows you to have more than one active profile.
- *Save between the marks.* You can set user marks at specific profile points. There can be only two user marks at a time, and their shape is different if you are working with global (sign ▲) or local (sign ▲) profile list.

If a polygon has been drawn on top of magnetic map, you have two more choices:

- All inside polygon. This means only profile parts inside polygon will be saved.
- Active inside polygon. Only active profiles are will be saved, and only the parts inside the polygon will be saved.

Figure 19 illustrates how this feature might be used to cut profile ends and produce new set of profiles.

5.2 Profile data data operations

These operations are used to change profile data, not their positions. They include simple profile editing by cutting part of the profile and data smoothing with cubic spline. Latter there can be used as low-pass or high-pass filters

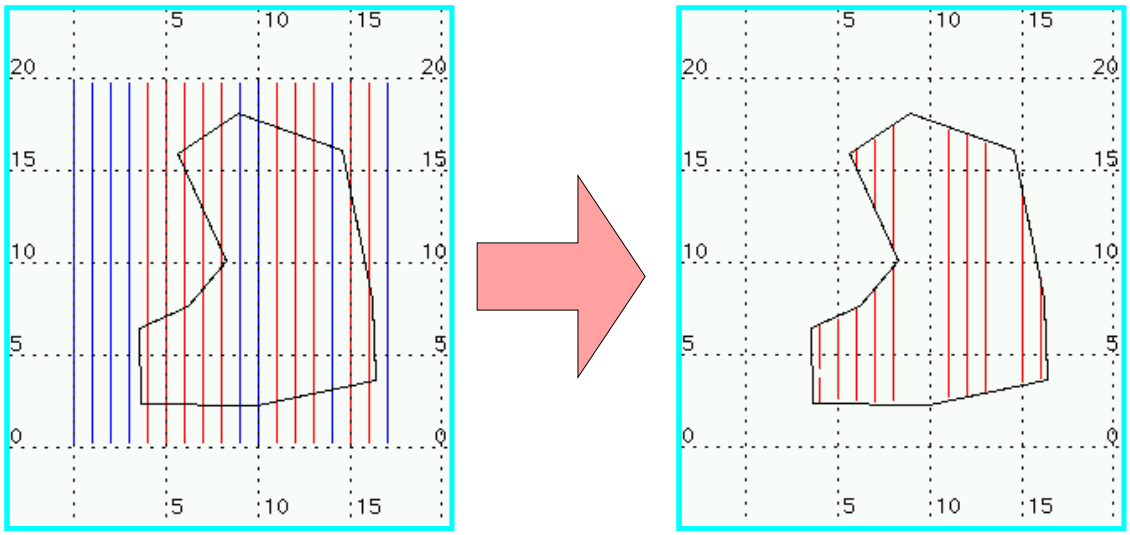

Figure 19: Profile cutting by saving an active inside the polygon. Active profiles are red, inactive profiles are blue. Function *All profiles in the window* has been used. While loading profiles back they become split by distance.

5.2.1 Cutting profile parts

These operations are applied to the active profile and based on user marks (or) which can be *up* or *down* arrows. To perform cutting the user must place marks on the appropriate place and call *Edit / Cut*. The operations are applied to all data channels if there are more than one. Terms *before* and *after* used below to denote distances from the beginning of the profile. It is strongly recommended to **use this feature when the profile is plotted as a function of distance** (plot mode *Along profile*). For example: you might be confused if your profile is going north - south and plotted as function of Y. Then when you cut the beginning of the profile the northern part is getting cut, not southern (part with small Y). In case of error call *Edit / Reload*. This reloads your profile data from hard disk and restores the initial profile configuration.

After profile being cut you have to redraw the map view (if you have one) to see any new profile location.

Here are four possible profile cut operations:

- *Cut from the start of the line to the UP marker* If *UP* marker is set the program removes all data from the beginning of the line untill the *UP* mark and redraws a profile view. If plot mode is *Along profile* it also shifts the data in the view because now the profile has a new starting point.

- *Cut part after UP marker to the end of the line*. If the *UP* marker is set, then all data after it gets removed and the profile view is updated.

- *Cut outside UP and DOWN markers*. This is the sum of two previous operations. *UP* and *DOWN* markers must belong to the same line. Then program counts points from the start of the line and removes all data before first mark and all data after second mark. The mark order is irrelevant (either UP or DOWN marks can go first).

- *Cut between UP and DOWN markers*. This is different from the previous operation, in that it acts between the marks. Important! *Data gets removed, not interpolated*. After you have saved the profile it has less data points then the original one (it also can have a gap and can be splitted into two profiles if you load it with a split by distance).

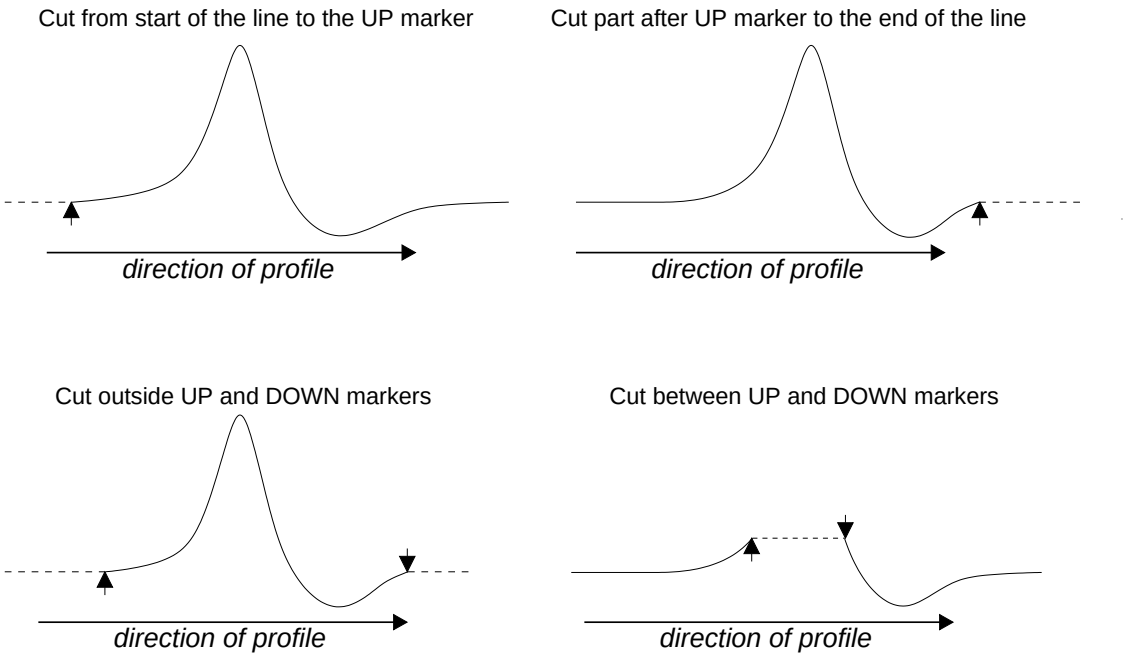
Cut from start of the line to the UP marker
direction of profile
Cut part after UP marker to the end of the line
direction of profile
Cut outside UP and DOWN markers
direction of profile
Cut between UP and DOWN markers
direction of profile

Figure 20: Different profile cutting modes.

Figure 20 illustrates possible cutting operations.

5.2.2 Data smoothing

MagPick allows simple data transformations such as smoothing using a cubic spline. Data is considered to be a function of a fiducial number *n* (first point of the line has number 0, next 1, etc). Note: this usage is internal (there is no view which shows $T(n)$; most similar is view $T(distance)$, but this is not the same). $T(n)$ gets approximated with a cubic smoothing spline with the *smoothing parameter*. Large parameter values provide an interpolating spline (typical values like $1., 10., 100$ or more) while small values (typically 10^{-4} or less) give a smoothed curve. The latter is of interest because it works as a low-pass filter. MagPick provides a view of both original and the smoothed curve (a typical result of a smoothing is shown on figure 21). As soon as the user is satisfied with the result he should commit changes and replace the original values with smoothed ones. There are two choices: the original curve gets replaced with a smoothed one (which is an equivalent to low-pass filter) or the original curve is replaced with the difference of the original curve minus the smoothed one, thus providing high-pass filter.

Smoothing also can be applied to the part of the curve between marks. In this case the value of the smoothing parameter is specified by the user. It is related to the middle of the interval. The ends of the interval have high smoothing values which essentially give an interpolating spline; then parameter decreases by the Gaussian law to the middle of the interval. Therefore the middle gets smoothed, ends stay similar to original values, thus discontinuity at the ends is not introduced.

One typical smoothing usage is stressing of the high frequency component on the stack profile plots. The stack profile feature itself can exclude the linear part from plotting. However in some cases the geological part of the field behaves as a higher degree function. The smoothing of the original values with following substraction of smoothed values from the original can stress local anomalies.

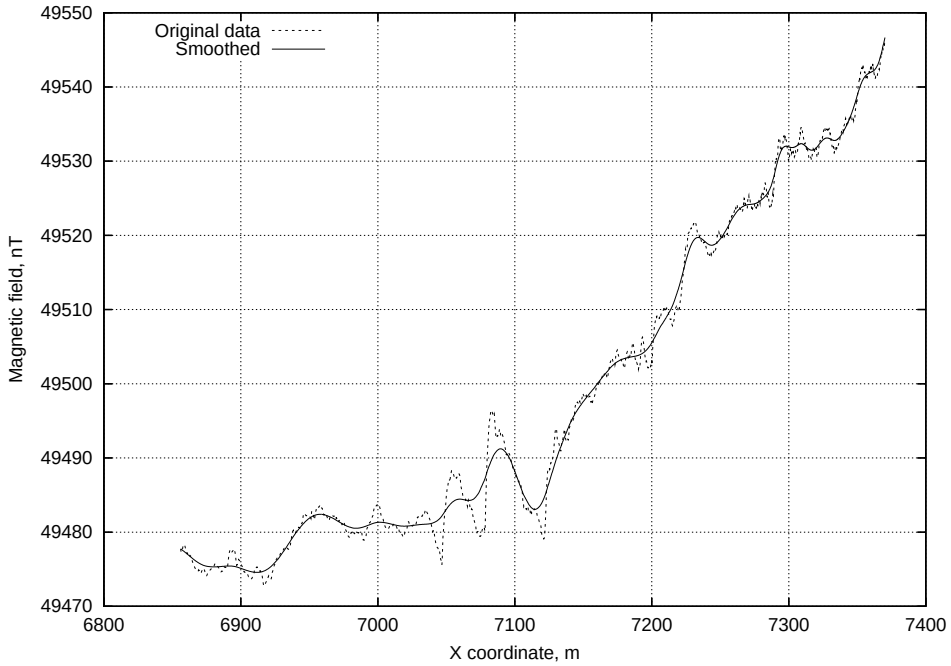

Figure 21: Data smoothing with cubic spline

To smooth profile data, use the following:

- Create a profile view (simple *Profile view* or *All profiles in the window* kind of view.) Then go to *Edit / Smooth*.
- *Smooth profile data* dialog appears on the screen. Here you can enter the next values:
    1. What to smooth: you can apply the operation to all profiles, currently active profile(s), or if there are two valid marks on the active profile the part between them can be smoothed.
    2. Enter the *smoothing parameter* which controls the smoothing degree. Smaller values provide more smoothing.
    3. Choose the color with which the smoothed curve is to be plotted.
- After you press Ok MagPick will proceed with the operation. This process can take different time depending on how many profiles and points you use. In the end profile the view gets updated showing the smoothing result.
- If you are not satisfied with the result you can repeat the smoothing again. The result of the previous operation is discarded.

- If you are satisfied then you can replace the original values with smoothed values by selecting *File / Accept* menu. There are four choices here: you can replace all profiles, only active profile, you can take just the smoothing result, or the difference original data minus the smoothed data.
- If for some reason you want do discard the smoothed curve, go to *Edit / Discard* menu. The smoothed curve will be erased.
- After you smooth data and replaced original data you should save the profile data or results will be lost after you exit the program. If you saved data with smoothed curve still on the screen then there is an additional column in the file called *T_calc*. This is result of the smoothing.

5.2.3 Linear data transformation.

Data smoothing represents a type of advanced transformation. However MagPick has a simpler ability, linear data transformation. Every profile reading can be transformed with the linear formula:

$$T_{new} = a \times T_{old} + b$$

Here T_{old} denotes the original profile reading, a is the *scale* and b is the *bias* of transformation. T_{new} is the transformed field value. The function can be applied to all data, to active profiles, or to the part of an active profile between markers. It might be useful when the data needs to be calibrated with a known coefficients or when some of the data was collected with a DC offset. The latter can happen if part of the magnetic data was collected at a different time with different Earth's main field.

Linear transformation is available from the profile view window under *Edit / Linear*. The dialog box is very similar to one for smoothing. There are few controls:

- Choose what to transform: All profile data, active profile(s), or if there are two valid markers on the same profile "between marks" can be chosen.
- Choose the color for transformed curve. The result of scaling will be displayed on the same axis till you *Accept* transformation.
- Enter *data scale*, *a*, and data *bias b*. These are the most important parameters. Please do not enter $a = 0$, it will turn all readings into a constant. If you want just add a DC offset, enter $a = 1$ and b equal to DC offset you want.
- In case of multi channel data transformation is applied to one channel at a time. Enter the channel number under *Channel to apply*. In many cases (only one channel) this value is 1.

After you press *Ok*, button T_{new} is displayed on the same axis as T_{old}. This gives you a chance to check that everything is right. After you satisfied with the result you can replace the original data with new data. Go to *Edit / Accept* and pick what you need. This dialog also is used to accept smoothed data. If you don't need transformation result go to *Edit / Discard.* If you want to restore original data after you did *Accept*, use *Edit / Reload*. The original values will be restored from file, and result of transformation will be discarded.

To make a change permanent you must save the profile (*File / Save*) You will need to construct a new profile list file or use *Simple load* to load the data next time.

5.3 Profile position operations.

Magpick also allows set of simple position operations which can be useful to alter or correct profile positions. These operations are available in map (grid) view under *Profiles* If there is no profile information loaded all the menu items are disabled. They become available after a profile is read from the disk.

All position transformation is first previewed by the user. The transformed is path plotted on the same map with a different color. If the user satisfied with the transformation he should replace the original positions with transformed position and save unfer different profile file name. There is no undo after this point. However profile data can be reloaded from the file and original positions restored. Use *Profile view* to do this. If you do several transformations sequentially you should commit changes (replace original with transformation result) after each transformation. For example: you shifted the profile along X and Y, then you smoothed the profile. If there was no *Accept* command issued after the shift operation then the smoothing would be applied to the original positions, not to the shifted.

5.3.1 Simple shift.

This very simple function adds the shifts dX and dY parallel to the coordinate axis. It is available under *Profiles / Shift XY*. After you call this menus item you should proceed as follows:

- Choose what you want to shift. It can be or *All profiles*, *Active profile* or *Between marks*. The latter is available if both marks are set on active profile.
- Then chose the color to plot shifted positions. This allows you to preview the result of transformation and compare it with the original positions. Note that the stack is not plotted if you have a shift preview (it may obscure all the picture).
- Finally specify the shifts along X and Y axis. Units are the same as original position information.

After you press the *Ok* button the program redraws a current map view (any other maps you have to redraw by hand). You now have a chance to compare the result of transformation with the original track. If you want to repeat it you just do it again. The previous result will be automatically discarded.

To accept changes go to *Profiles / Accept*. All original profile data is replaced with the transformed data (only for profiles where you did transformations). You must save the profile data or the result will be lost after you exit MagPick.

To discard transformation results go to *Profiles / Discard*. The grid view will be redrawn and transformed part will disappear.

5.3.2 Spline smooth.

Similar to the profile data profile X, Y positions also can be smoothed with a cubic spline. A good example of this is when you are plotting a stack profile of magnetic data with the field plot perpendicular to the track. If the GPS (Global Positioning System) has been used to acquire position information chances are that the path is not a smooth curve (individual data points jump around). If you use such a path to prepare magnetic field stack plot it will result in an erratic picture. After a certain degree of smoothing, the positions remain almost the same but path becomes much smoother and therefore can be used as a base line for a stack plot.

It should be noted here that MagPick actually constructs two splines: $X(n)$ and $Y(n)$ where X and Y are positions and n is a fiducial number. Each curv,e $X(n)$ and $Y(n)$ gets smoothed individually. The results are combined into (X,Y) pairs which represent smoothed positions. It would be better if the program were using *time* instead of the fiducial number n (using of n implies that position data have fixed sample rate). Usage of the fiducial number instead of time could result in unacceptable results when data has long position gaps. Smoothed curve will spread the positions points over these gaps thus covering them almost equidistantly.

The rule of thumb is next: Position smoothing works well when a time interval between data points is constant or almost constant.

To smooth position data follow the next steps:

- After profile data is loaded and map a (grid) view created, go to *Profiles / Smooth XY*. A dialog identical to data smooth dialog appears on the screen.
- Choose what you want to smooth. It can be or *All profiles* or *Active profile* or *Between marks*. The latter is available if both marks are set on active profile.
- Specify a *smoothing parameter*. Remember that the smaller values provide more smoothing. Value 10^{-1} is good to start with. Smoothing may fail if this parameter is too small (less then 10^{-10}.)
- Then chose a color to plot the smoothed positions. This allows you to preview result of smoothing and compare it with original positions. Note that a stack is not plotted if you have a smooth preview (it may obscure all the picture).

After you press the *Ok* button, the program redraws the current map view (any other map views you have to redraw by hand). You have now chance to compare the smoothing result with original track. If you want to repeat it just do it again. Previous results will be automatically discarded.

To accept changes go to *Profiles / Accept*. All original profile data is replaced with transformed data (of course only for profiles where you did transformations). You must save the profile data or the result will be lost after you exit MagPick.

To discard the transformation results go to *Profiles / Discard*. The grid view will be redrawn and the transformed part disappears.

5.3.3 Shift / dragging along profile.

Typical marine magnetometer systems consist of a GPS receiver mounted on the ship and a magnetometer fish being dragged behind. It is clear that the magnetometer position is not the same as GPS antenna position. The distance between antenna and tow winch and tow cable length must be taken into account to find the real sensor position. This problem is complicated and may have different solutions (based on the price paid the system) including usage of acoustic underwater positioning systems, gyro compass on board, or complex cable dynamics calculations. **Magpick** provides two the simplest ones: 1) a simple shift *along* the recorded GPS track 2) using simple approximation of tow system with *dragging* technique. Neither method takes into account possible difference between ship heading based on position information and the real ship heading which can be obtained with gyro or magnetic compass.

Both methods are available under *Profiles / Drag profiles(s)* in map (grid) view. The profile data should be loaded. There is no option ”between marks”. The transformation is applied to the entire line of data or to all lines. To proceed with transformation, perform the following:

- After profile data is loaded and map (grid) view created, go to *Profiles / Drag profile(s)*.
- Choose the item you want to drag. It can be or *All profiles* or *Active profile*.
- Specify *shifting method*. It can be *Drag profile* or *Shift along profile*. In the first case the program simply moves the data points along the track, in second case it uses the dragging method.
- You might check the button *Apply transformation in reverse order.* This is useful if your data has a reversed order in the file.
- Enter shifts along and perpendicular to the profile. The latter is positive to the right if you look along the track and negative to the left. To apply a perpendicular shift the program finds a normal vector at every point of the path.
- To transform first point of the track program needs to find a direction of motion at the beginning of the line. To do so it uses first part of the track being approximated to a straight line. The distance used for such an approximation is entered under the *Distance to find direction*. This value also used to find a direction at every point of the line. This value can not be zero.
- Finally chose the color to plot the transformed positions. This selection allows you to preview the result and compare it with the original positions. Note that the stack is not plotted (it may obscure all the picture).

After you press the *Ok* button the program redraws the current map view (any other maps you have to redraw by hand). You now have a chance to compare the result with the original track. If you want to repeat you just do it again. The previous result will be automatically discarded.

To accept changes go to *Profiles / Accept*. All the original profile data is replaced with transformed data (of course only for profiles where you did transformations). You must save the profile data or the result will be lost after you exit MagPick.

To discard the transformation results go to *Profiles / Discard*. A grid view will be redrawn and the transformed part disappears.

5.3.4 Dragging method details.

Here you can find a brief description of the method used to calculate the position of the fish being dragged behind the boat. Text below refers to figure 22.

Goal: Let's consider the object (magnetometer fish) being dragged behind the boat with constant (and known) tow cable length. The boat is equipped with GPS receiver and therefore its position is known. The task is to provide a reasonable approximation for the magnetometer fish position based on GPS readings and the cable length.

Solution: This solution is an approximation and does not take into account a 3-D configuration (depth) and some physical effects like friction. Nevertheless it gives reasonable behavior even if ship makes a turn.

We assume that we know the position of the ship (**A**) and the magnetometer fish at time t_0 **N** (see fig. 22) as well as the cable length. At time t_1 we know the position of the ship **B** but do not know position of the fish **M**. To find the fish position we draw a stright line **NB** between the old fish position **N** and new ship position **B**. Then we use a straight line from **B** to **N** and place the fish at a cable length distance behind the ship on the line. New point **M** is the estimated position of the fish time t_1.

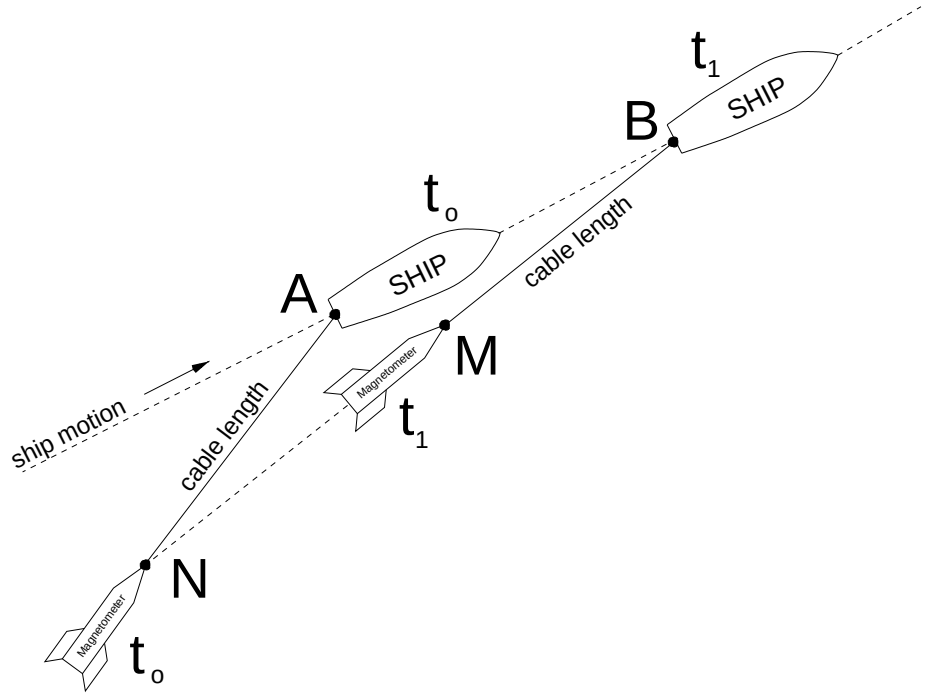

Figure 22: Calculating magnetometer offset with dragging

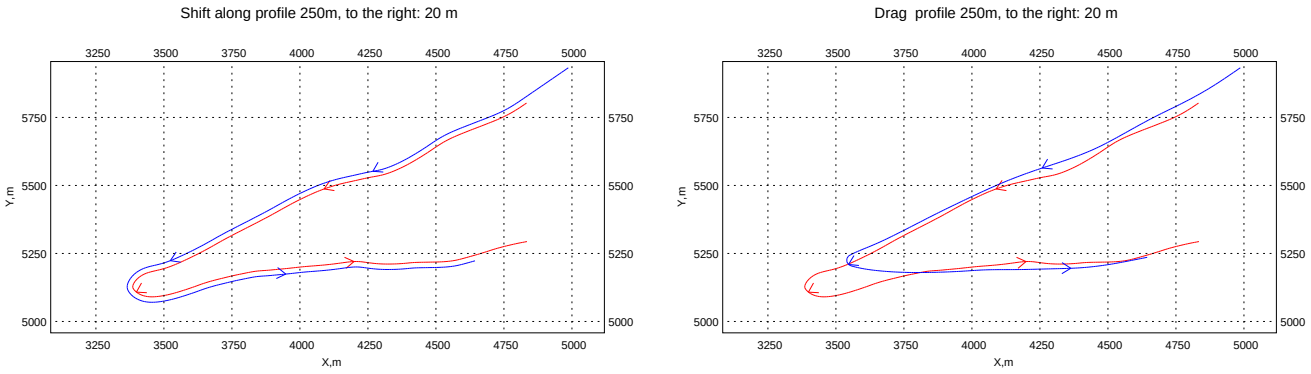

Figure 23: Example of calculating magnetometer offset with simple shift and dragging

It can happen that distance **BM** is greater than **BN** (if ship does a sharp turn). In that case the position of the fish is not changed (literally fish should sink in this case).

These calculations are repeated for each GPS point.

Method explained above assumes that the fish position at time t_0 is known but in general we do not know this. Therefore to start the calculation process we need to find the initial fish position. Different techniques might be employed for locating the position. The easiest one follows: use the initial part of the recorded path to find direction of motion, by approximating these positions with a stright line using the least-squares method, and count the cable length along this line. This gives a reasonable estimation for the initial fish position. When the initial position is selected the dragging method can be used. After short distance influence of initial position becomes negligible.

Potential problems: It should be noted that this method is not designed to work with sharp turns. It does not take into account the depth of the fish (if fish is deep then horizontal distance is less than

the total cable length). Another problem is that the GPS normally is not mounted at the same point where tow winch is, therefore the effective cable length should include distance thr GPS to winch offset. Simple geometry calculations should be used to estimate errors introduced by these sources for each particular configuration.

Figure 23 shows two different offset calculation methods. They are based on real GPS data which represents a ship turn after it passed the Golden Gate Bridge in San-Francisco Bay (the data was converted into short UTM). MagPick was used to calculate the offset with a hypothetical cable length 250 m and an offset to the right 20 m (offset was taken *after* dragging has been used.) The left pane represents the result of shift along a GPS track, and the right represents a result of the dragging method.

6 UTM / Gauss-Kruger transformation in magpick

MagPick is supposed to work with local (projected) magnetic data. Usage of geodetic coordinates is possible but depreciated. Instead the user should project his or her data into the UTM (Universe Transverse Mercator) projection (or any other suitable projection). UTM is supported by MagPick internally). False northing and easting should be introduced to avoid large numbers. MagPick stores the position as single precision numbers (allows double the amount of data loadable into program). The full UTM form (as well as geodetic) would lead to lost of accuracy.

The following is an example of the data processing:

- Prepare your data in the form X, Y, field (columns with northing, easting and data). Northings and easting may be in full or short form. If they are full, you should apply false northing and easting during profile reading.
- Make sure of the UTM parameters you are using. This includes false northing and easting. It is better if you write them in a file and keep with the data.
- After the profile is loaded make a grid. This grid will be related to the local short UTM system.
- Set up UTM transformation in MagPick exactly the same way as you used for the initial projection. Go to *Options/Utm setup* and proceed.

Figure 24 shows the UTM setup dialog in **Magpick**. You should specify an ellipsoid name (directly enter the ellipsoid parameters, if your ellipsoid is not listed), central meridian, scale factor (normally 0.9996 for UTM, 1 for Gauss-Kruger), and false northing and easting. For your convenience an easy check *UTM calculator* is provided. Using this tool you can convert Lon/Lat coordinates to Northing and Easting and vise versa. It is recommended to use pair of points with known UTM/geodetic coordinates to check your setup before going to work with whole data set.

Knowledge of the central meridian or zone number is one of the problems using the UTM system. Six degree zones start at 180W and go to 180E. Magpick allows you to find a zone/central meridian based on your data. The following shows how to proceed:

- Check *Set central meridian from first sample*
- Go to *UTM calculator* and enter Latitude and Longitude of your location.
- Press *Lon/Lat->UTM*. Read Northing, Easting, UTM zone and central meridian. The central meridian value in UTM setup dialog is updated automatically.

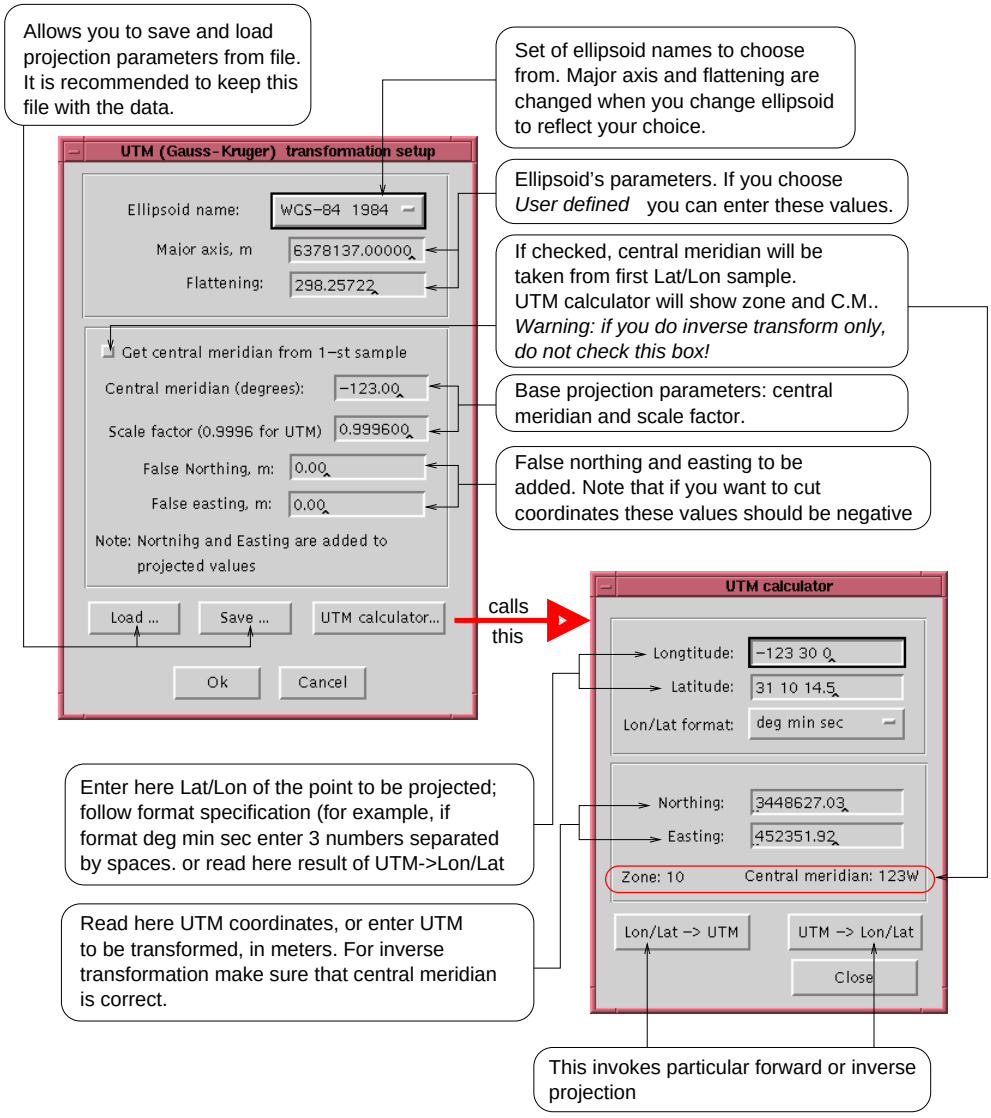
Allows you to save and load projection parameters from file. It is recommended to keep this file with the data.
Set of ellipsoid names to choose from. Major axis and flattening are changed when you change ellipsoid to reflect your choice.
Ellipsoid's parameters. If you choose User defined you can enter these values.
If checked, central meridian will be taken from first Lat/Lon sample. UTM calculator will show zone and C.M.. Warning: if you do inverse transform only, do not check this box!
Base projection parameters: central meridian and scale factor.
False northing and easting to be added. Note that if you want to cut coordinates these values should be negative
UTM (Gauss-Kruger) transformation setup
Ellipsoid name:
WGS-84 1984
Major axis, m
6378137.00000
Flattening:
298.25722
Get central meridian from 1-st sample
Central meridian (degrees):
-123.00
Scale factor (0.9996 for UTM)
0.999600
False Northing, m:
0.00
False easting, m:
0.00
Note: Nortnihg and Easting are added to projected values
Load ...
Save ...
UTM calculator...
Ok
Cancel
calls this
UTM calculator
Longtitude:
-123 30 0
Latitude:
31 10 14.5
Lon/Lat format:
deg min sec
Northing:
3448627.03
Easting:
452351.92
Zone: 10
Central meridian: 123W
Lon/Lat -> UTM
UTM -> Lon/Lat
Close
Enter here Lat/Lon of the point to be projected; follow format specification (for example, if format deg min sec enter 3 numbers separated by spaces. or read here result of UTM->Lon/Lat
Read here UTM coordinates, or enter UTM to be transformed, in meters. For inverse transformation make sure that central meridian is correct.
This invokes particular forward or inverse projection

Figure 24: UTM setup and UTM calculator in magpick.

Note that the *UTM calculator* is a modaless dialog box. It means that you can do changes in the main UTM setup dialog without closing UTM calculator.

Besides the UTM calculator MagPick uses the UTM transformation in the next places (this might be extended in the future):

- The status line (coordinates of the mouse position) inverse UTM is used. This means you can see the position of the mouse cursor in Lat/Lon. To utilize this feature go to *Options / Status line...* Here you choose the format of the coordinates in the status line (for example, if your data already are Lat/Lon, you can use degrees, minutes seconds) and (if data in UTM) apply inverse projection (Check *Inverse UTM*). This means that every mouse location position is projected back to geodetic and formatted accordingly.

- Pick export. For example, when you need the final locations of your picks you can obtain them in the geodetic system, applying inverse UTM during the export. The UTM transformation setup can be called directly from the export dialog box.

- DXF export to AutoCAD. You can apply the inverse UTM transformation during export to obtain drawing in geodetic coordinates.

It is recommeded you save the current projection parameters (button *Save* in UTM setup dialog box) and keep this file with the data. Each time you are working with the data load this file again (button *Load* in UTM setup.)

For a good reference on UTM and other projections see [6]. There are a lot of references on the Internet (for example, http://www.cnde.iastate.edu/staff/swormley/gps/gps.html, http://everest.hunter.cuny.edu/mp/).

Note for users in the Southern hemisphere: by convention, we should add 10 000 000 m to UTM northing for points located south from equator. *Magpick does not do it*. To do so, you should reflect that addition in *False northig*.

7 Earth's magnetic field model (IGRF).

To estimate location and amplitude of the magnetic sources parameters of the main Earth's magnetic field (see also figure 29) should be known. International geomagnetic reference field [5] normally provides these values. It allows you to find the main magnetic field parameters for any point on the Earth between years 1900 and 2005. This model will be extended in future as new observations (which are conducted all over the planet) become available.

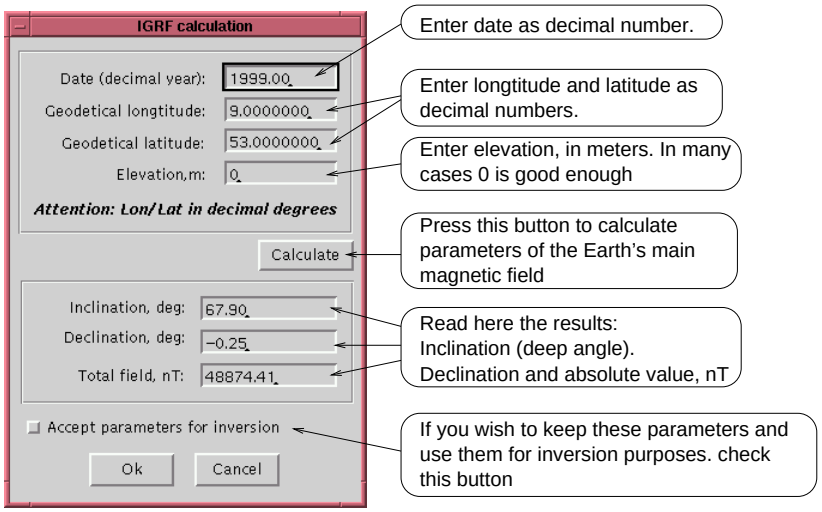

Figure 25: IGRF model in magpick.

Magpick has an embedded IGRF model and an external file with coefficients `igrf.dat`. The model was obtained from http://www.ngdc.noaa.gov. The user may need to get a new file `igrf.dat` from the site as soon as it becomes available.

Dialog 25 shows how the IGRF model can be used. It gets called from *Inversion / IGRF model...*. You should enter the data and geographical position. The main magnetic field changes from point to point smoothly, therefore the high precision of position and date is not required. It is acceptable if you are in the 25 km range and within a few month from your place and date of measurements. (you can check how the field changes by entering different positions and dates). The western longitude and southern latitude should have a negative sign. As soon as you entered these values press *Calculate*

button and read the results. If you want to use result for an inversion (have these values automatically appear in inversion dialog box) check *Accept parameters for inversion* - MagPick will store the last calculated values. These values also affect ”reduction to the pole” group.

This is list of typical problems you may encounter:

- The date you entered is out of model scope (1900-2005 presently). Obtain a new file `igrf.dat` and replace the old one.
- The program can not find file `igrf.dat`. Make sure this file is exists in the same subdirectory as the MagPick executable. Make sure you call MagPick with the full path (or its location is listed in system PATH variable)

8 Potential field transformations.

In many cases the total field anomaly can be treated as a potential field which allows the use of some standard transformations. These are upward / downward continuation, pole reduction, decomposition of the total field into its components. All these transformations are based on the Fast Fourue Transform (FFT) and are available in MagPick.

To learn more about the theory of these transformation please see [7].

Due to the nature of an FFT transformation you can get a considerable side effect if your grid has a small number of cells or if you have a considerable gradient across your area.

Attention! All these transformations are working with anomalous magnetic field, NOT with the total magnetic field measured by the total field magnetometer. Before using of any of these transformations you should subtract average field value of IGRF predicted value from your data

8.1 Upward continuation

Because of the potential nature of the gravity and magnetic field they can be calculated at any elevation above (and in some cases below) the level of measurements. That is if there are no gravity or magnetic sources between these two levels. This procedure is called *upward continuation of potential field.* It is generally a useful and physically meaningful filtering operation. It allows you to smooth the field and eliminate small anomalies from the near surface objects. Subtracting the upward continued field from the original field reduces the influence of the deep objects, therefore reducing the regional trend, stressing a magnetic response from shallow objects.

Theoretically the field also can be continued downwards untill the continuation level does not cross any field sources. However it has been proved that this operation is unstable. It greatly magnifies existing noise and makes the field unusable. To cope with this problem relaxation (regularization) can be used. This may help but only to certain extent.

Magpick uses very simple kind of Tikhnonov regularization. In the spectral domain upward continuation can be written as

$$F(u,v) = s(u,v) \times f(u,v) \Longrightarrow F(u,v) = \frac{s(u,v)}{1+\alpha s(u,v)^2} \times f(u,v)$$

here $f(u,v)$ is the spectrum of the field to be transformed. $F(u,v)$ is the spectrum of transformed (upward or downward continued) field. $s(u,v)$ is the spectrum of the transformation, and α the small regularization parameter. You should try several values of α to find a best for your case (start with small vales like 10^{-5})

The field in the current grid view can be upward continued by calling the *Operations / Upward continuation* menu. If function is called for zoom window, only data in zoom window is used. (not the whole grid.) The next dialog box appears on the screen (see figure 26)

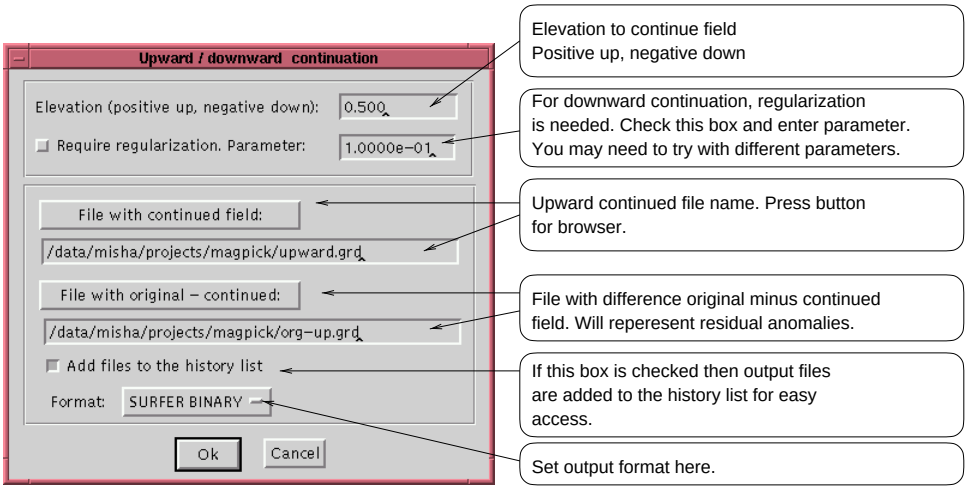

Figure 26: Upward continuation dialog.

8.2 Synthetic horizontal and vertical gradients.

As you saw above the potential field can be upward continued, and therefore a vertical gradient also can be calculated. Magpick allows you do to this operation, as well as a calculation of horizontal gradients. This option is available under *Operations / Gradients*.... Here you can choose the type of gradient (vertical, horizontal or absolute value of horizontal gradient). For a horizontal gradient you have to enter the direction (positive clockwise from your Y axis).

Because these operations can be numerically unstable you have an option of simultaneous upward continuation to cope with possible noise increase. Again, you may need several attempts to find the best result.

8.3 Reduction to the magnetic pole and pseudo gravity transformation

It was shown (see [7] for reference) that total field anomalies can be reduced to ”anomalies on the magnetic pole” if the direction of the Earth’s magnetic field and the direction of object magnetization are known.

Figure 27 shows the relation between the field measured at the middle magnetic latitude (a), at the magnetic pole (b), and the gravity field (c) from the same object. Curve (a) has a complex shape and the real location of the object is somewhere between minimum and maximum. The actual location depends on the Earth’s field inclination and declination, as well as magnetization direction of the object. On the magnetic pole (b) the Earth’s field is directed downwards. Induced magnetization is directed downwards too. In this case (b) the main maximum of the field located right above the object. Thus the horizontal location can be easily found. Plate (c) shows the gravity field from the same object. It is similar to field on the magnetic pole but does not have side minimums.

Theoretically when you apply reduction to the pole transformation all the specific (maximum - minimum) shapes of the anomalies should change into simple ones. However to do so you must

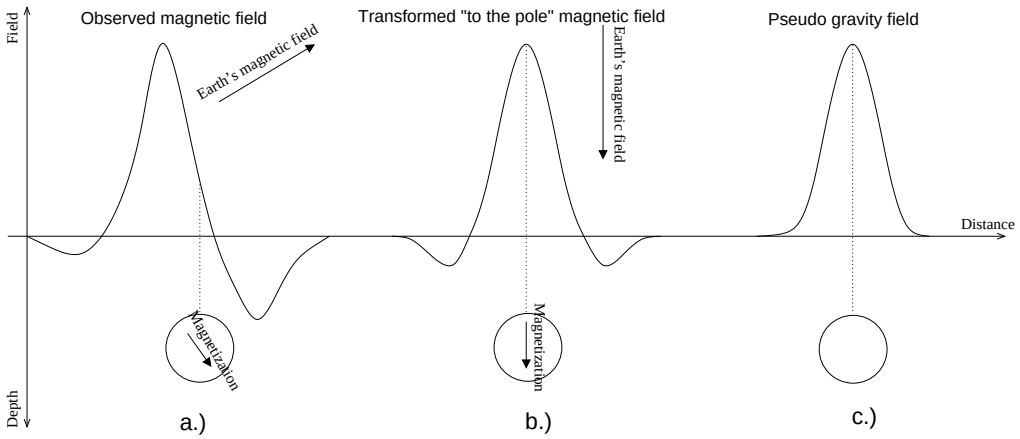

Figure 27: Relation between observed, reduced to the pole and pseudo gravity fields.

know the direction (inclination and declination) of the object's magnetization, which is generally unknown. In some cases you can assume that objects have only induced magnetization and use the IGRF model to find it. (in this case the direction of magnetization coincides with direction of Earth's magnetic field). Different objects also can have different directions of magnetization.

Because of this and other reasons do not expect that a transformed picture will be fairly simple. Some anomalies could be transformed, some not. Reduction to the pole also might be an unstable operation on the equator (see [7] for details.)

Similar to the reduction to the pole, the magnetic field can be reduced to the different direction of magnetic Earth's magnetic field and magnetization (reduction to the pole just a special case of such a transformation). In this case you should enter explicit directions of new field and magnetization.

All operations listed above could increase noise. To cope with this the option of simultaneous upward continuation (which acts as low-pass filter) is provided. Use zero elevation to disable this option.

These transformations are available under *Operations / Reduction to the pole* and *Operations / Pseudo gravity*.

Figure 28 shows the dialog box where transformation parameters are set (pseudo gravity dialog box is similar).

1. Enter inclination and declination of the Earth's magnetic field for your area. If you do not know, go to *Inverse / IGRF model* and calculate it (you need to know geographical coordinates of your place.) To use calculated parameters check *Accept parameters for inversion* and MagPick will use them when ever possible.

2. Here is a similar set of parameters but for magnetization. We recommend to start with the same values as with the Earth's magnetic field (this implies induced magnetization only).

3. The Azimuth of you local X-axis. It is 90^o if it points East.

4. Check this box if you want reduction to the pole, and the four fields below will be filled in automatically. If you want to recalculate field to the new directions you should not check box, enter desired directions directly.

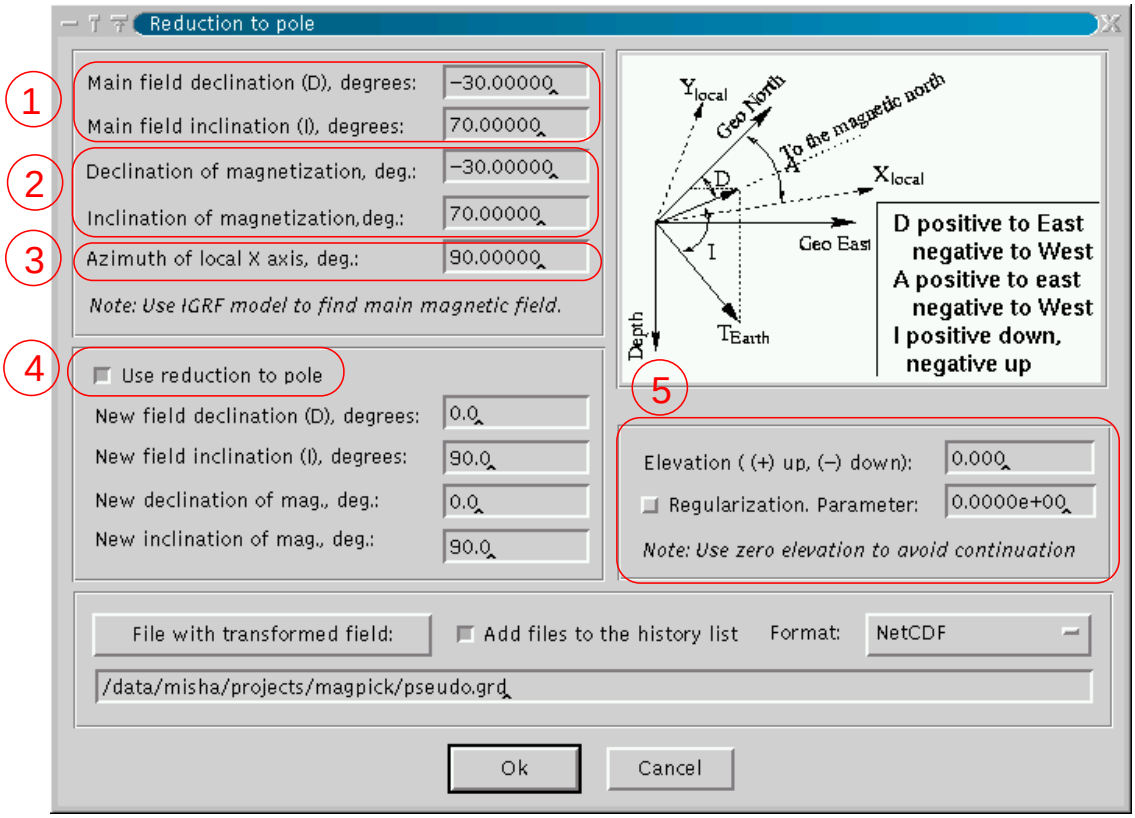

Figure 28: Reduction to the pole dialog in magpick.

5. You need this group if the results of your calculations are unstable. Apply some upward continuation as a low-pass filter, it may help.

9 Estimation of magnetic sources.

Along with the simple magnetic picking facilities, MagPick has an internal option of magnetic modelling. Presently it supports only three kinds of sources - uniform magnetised sphere, (magnetic dipole), magnetized line and uniform infinite current (power line). It is possible to find a few sources simultaneously (in case of dipoles or power lines). Parameters that need to be estimated for each dipole are: three components of the total magnetic moment of the body and three parameters (X, Y, Z) of its geometrical location. In addition a simple function to fit background field can be found. Because of it method can be applied directly to the measured field without calculation of the residual field.

In general searching of the magnetic dipoles is an iterative process which requires knowledge of their initial positions. MagPick uses the locations of the middle points of the simple picks as initial locations. All picks done in the current map view are involved in the estimation. If user does not pick any points, the inversion procedure can not be started.

9.1 Magnetic modelling based on grid data.

With a magnetic map loaded into the one of the map views, the process of inversion involve following steps:

1. Interpreter visually analyses all areas and makes a decision about the approximate number of dipoles. The interpreter decides where to start and how to proceed through the area.

2. Part by part the interpreter selects subwindows by means of the zoom facility. The aim is to get a subarea with one or more clear magnetic anomalies. Subwindows also can be zoomed into if needed.

3. The interpreter does one or more simple picks to hit approximate locations of the magnetic dipoles. Then *Inverse.../Run..* is invoked, inversion parameters are set (see description below), and the program does iterations. During this step the user interface is blocked, and the interpreter has to wait until it finishes.

4. After inversion has been completed the results appear in the work sheet table and are plotted on the top of all maps with numbers. For inversion based on the grid sign $+$ is used.

5. The interpreter analyses the results and decides whether or not to repeat inversion with different parameters. The interpreter can open output grids with synthetic and residual fields to estimate quality. Then initial depth, susceptibility, etc. can be changed and *Run...* step is repeated.

6. By repeating the above steps with different initial parameters the interpreter can get an idea how stable estimation procedure is, and what are reasonable estimations and their errors. If results are close to each other, procedure is stable and location can be estimated. If not, the interpreter may re-select or even abandon the area as non-interpretable.

7. After a number of inversions it is possible to discard all or part of the results obtained in a given window. To do that go to *Inverse... /Remove results....* Here there is a list with locations obtained in the particular window. To remove, select all or part and press Ok. The work sheet and map views are altered to reflect new results table.

To find magnetic dipoles, information about the Earth's magnetic field and orientation of the local coordinate system has to be provided. These values have to be filled in using the "Inversion parameters" dialog box. To understand what they mean refer to figure 29.

Here is complete list of inversion parameters.

- *Main field inclination*. Inclination of Earth's magnetic field in the geographical system - angle **I** of figure 29.

- *Main field declination*. Declination of Earth's magnetic field in the geographical system - angle **D** of figure 29. Positive to the East.

- *Azimuth* of X axis. Azimuth of you local X axis - angle **A** of figure 29. In case your local X coincide with geographical east $A = 90^o$ Positive to the East.

- *Total magnetic field.* Magnitude of $\vec{T}$ on figure 29.

- *Susceptibility,cgs.* Susceptibility per volume. This value can be used for mass estimation. It is supposed to be known.

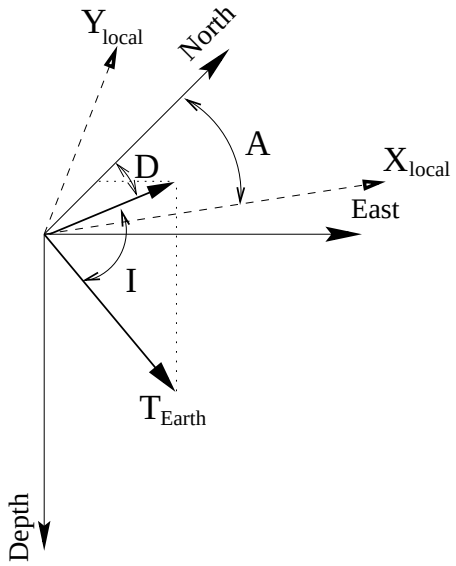

Figure 29: Coordinate system

- *Remanent, gauss*. Remanent magnetisation per volume. Used for mass estimation.
- *Elevation.* For grid inversion all data points should have the same Z coordinate. You can introduce this value here. Note that you should then set initial depth of dipoles correctly. Z axis goes down.
- *Margin space.* If you wish you can use only part of the window in the estimation by setting appropriate margin.
- *Number of iterations.* The limit for the iterations program to perform inversion. Estimation is stopped after the iteration counter exceeds this value.
- *Limit to stop.* After each iteration MagPick calculates the discrepancy between observed and synthetic field. If there is a difference in these values taken on two sequential iterations less then this limit, estimation procedure stops.
- *Initial depth.* Initial depth for the whole dipoles. Sometimes the estimation procedure can be sensitive to value (for instance, it can put dipoles above observation level.) In that case take a new value and repeat.
- *Density*. If you want a mass estimation, the density value is needed. For instance if susceptibility is in CGS units and remanent magnetisation in gauss and you want to have mass in kilograms, it should be the mass of one cubic centimeter in kilograms.
- *J scale*. In many cases the mass estimation will fail. MagPick estimates the total magnetic moment of the dipole in cgs units anyway. Because it is known that 1 ton of iron has dipole moment in range $10^5 - 10^6$ cgs a rough method of mass estimation can be applied. Just put the appropriate scale factor and J_{total} will be in the mass units.
- *Induced only.* If you guess that the body can have only induced magnetisation, check this box. It is means instead of three components of magnetic moment, the program estimates only one because the direction is known. Mass estimation becomes trivial then.

- *Linear solution only.* In some cases you can presume that you know the source location and you wish to find only magnetisation. Then check this box. The program will not do iterations because the problem is linear.

- *Grid type.* This is the format of output synthetic grid file. There are two choices - Golden Software ASCII grid and netCDF binary grid. The last one only is needed if you work with GMT cartographic system.

- *Position file*. Besides appending results of estimation to the worksheet, the program saves the position in the file which has a format compatible with the pick file (i.e it can be loaded into MagPick as a new pick file). This feature is obsolete. The file is overwritten after each inversion. To keep the original file change name by means of the *Change...* button.

- *Calculated grid.* Synthetic field after calculation should be loaded into a new map view to compare with observed field. You can change file name by means of *Change...* button.

- *Difference.* The residual grid is equal to the observed minus the calculated. It is worth to make new map view and load it to see how it looks like. You can change file name by means of *Change...* button.

- *Start iterations.* This button starts the inversion procedure. Remember that if you choose the wrong parameters (for instance you started the inversion for all your map and all potential sources) the calculation can be endless. Then you will have to stop it.

During inversion the program prints results of each iteration on the screen (Unix systems only). Here is an example of such output:

```
N: 11 Discrep:52.47  Lin:4.97e-03 Non-lin: 2.42e-01 lev:49729.32
```

1. *N: 11* Current iteration number.

2. *Discrep:52.47* Current discrepancy for given iteration, nT. This number has to be reduced during calculation. But in some cases program can not perform optimisation (i.e. solve inversion problem). Then this number can increase or oscillate.

3. *Lin:4.97e-03* Ratio between minimum and maximum singular values for linear step of inversion. Small numbers (about machine epsilon 1.e-7) show that a problem mathematically ill-posed. It can occur in case of large number of sources or their improper initial locations.

4. *Non-lin: 2.42e-01* The same as above, but for non-linear step. Has the same meaning.

5. *lev:49729.32* Constant part of background function estimated on each iteration.

After calculation finishes the results appear on the screen and are stored into the special list. If you have opened a worksheet window (see below) a new line is added to the worksheet. All map windows are updated automatically o show horizontal coordinates of the found targets.

9.2 Magnetic modelling based on profile data.

Magnetic modelling based on profile data is similar to the inversion based on maps, but has some significant differences:

1. The start of inversion is possible only from the ”Profile inversion (all profiles in current window” window. Only activated profiles and subsets of profiles (and therefore visible inside window) are used for interpretation. It could easily happen that many profiles cross a given window. The interpreter should decide which profiles are suitable for inversion and select them. To make this happen new item is added to the map view menu: *Edit.../Pick profile*. Activate this menu item, move the mouse cursor to some profile and click left button. Profile is deactivated (or activated) and therefore all subsets disappear from profile view window. If *Browser...* dialog box is opened, list selection is altered too.

2. Depending on on discretization interval along the profile number of data points used in the profile inversion could considerably exceed number of data points used for map based inversion. Therefore the time of computation might increase.

3. Instead of relative depth, real depth is used. This means each point of profile involved in the inversion is taken with its z - coordinate. It allows usage of the data obtained at different elevations. With other side it means that all z values are measured relatively to some predefined system. In the case of GPS heights they are geodetic elevations.

4. Because of the above reasons the initial depth of the source has to be specified carefully to avoid choosing it above the data.

5. In some cases the Z values have considerable noise and can not be used directly for interpretation. In such a case smoothing of elevations is required.

To start a profile based inversion, a set of profiles have to be loaded into the program (see above). Then the interpreter can view the magnetic maps if available or browse profiles as T(dist) graphs. The aim is visual selection of potential places were sources might be located. When such a place is selected (by map view or by means marker facilities on the profile view) the interpreter does ”zoom” in surroundings and creates new map window. This last window is used as a parent for ”profile inversion” window. After the ”profile inversion” is opened the interpreter can view all profiles crossed and select a subset of them. Very often the interpreter has to change decimation of data to get all available points into the inversion. All these options can be reached in *Browser...* dialog box.

The next most important step is choosing the initial positions of the sources. It is done exactly the same way as in the case of grid based inversion, by means of picks on the map. Note that it is possible you do not have a real grid and must use a dummy grid (implicitly created by MagPick or loaded from dummy grid file). It might be very useful to uncheck *Snap to grid* to allow picks to be located anywhere.

After the profile selection is made the estimation procedure can be started. Choose *Inverse... / Run...*. Dialog box similar to the one in the case of grid inversion appears on the screen. Here is the difference:

- *Smooth Z parameter* Checkbox and value. In case you have noisy Z values it is possible to apply a simple method of spline smoothing. If you need it, check it on. The normal value for a smoothing parameter is 1.e-5; less parameters give more smoothed curves. Normally changes of orders required to feel a difference.

- *Average data depth* This value is for information only. Program calculates the average elevation of all the data points to get an idea about the possible initial source depth specified by the interpreter. *Initial depth* should be bigger than the average depth. It is possible that in the case of improper initial depth during iterations the program can move sources above the observation level. Change the initial depth and repeat calculation in that case.

- *Induced only - Linear solution only* - not implemented for profile inversion.

- *Output file*. Instead of creating calculated and observed grids the program writes an ASCII file file with that information. It stores the calculated field inside the profile structure. This means you are seeing the calculated field immediately after calculation. This information disappears if you repeat calculation or close profile inversion window.

During the calculation itself, the program posts on the screen the same messages as in the case of a grid based inversion (Unix version). After the program finishes it creates an ASCII file with the following structure:

- Line: sign ”#”, space and name of the file

- For all datasets activated in this file trough two empty lines six columns of numbers:

  1. X coordinate.
  2. Y coordinate.
  3. Original Z coordinate.
  4. Smoothed Z coordinate.
  5. Original magnetic field.
  6. Calculated magnetic field.

- Next line with ”#” and name of the file.

This file can be used for further presentation or processing. It is overwritten for each inversion. In order to save data you have to change its name before the next inversion starts.

It is possible that there were many inversions done in the particular window. Until the window is closed the program keeps track of all of them; open *Inversion... /Remove results...* and you will see the beginning of the line for each inversion that belongs to the window. Thus unnecessary results might be safely removed and a work sheet window automatically altered. If a window has been closed the only way to remove the results is to do it directly in the work sheet window.

9.3 Magpick worksheet - results of inversions.

For convenient storage and presentation of the inversion results, MagPick maintains special object work sheet (electronic table). This object is global. Only one copy exists during a session and all the inversion results are appended in it. The work sheet can be saved or loaded from file. In case you are about to quit MagPick without saving of modified work sheet you are warned and allowed to save it.

The work sheet file has a column structure. Here is the meaning of the columns:

1. Type of results letter ”G” for grid results or letter ”P” for profile results.

2. X - coordinate of the dipole
3. Y - coordinate of the dipole
4. Z - coordinate of the dipole
5. attempt to estimate mass - root one (see below)
6. attempt to estimate mass - root two (see below)
7. accuracy of the fitting of the total magnetization during mass estimation.
8. X coordinate of low left corner of the window where inversion has been made.
9. Y coordinate of low left corner of the window where inversion has been made.
10. X coordinate of upper right corner of the window where inversion has been made.
11. Y coordinate of upper right corner of the window where inversion has been made.
12. Inclination of the total magnetization vector in the geographical system, degree.
13. Declination of the total magnetization vector in the geographical system, degree. (positive to the east)
14. Magnitude of total magnetization possibly divided by scaling factor.
15. X - component of magnetization vector, in the local system, cgs units.
16. Y - component of magnetization vector, in the local system, cgs units.
17. Z - component of magnetization vector, in the local system, cgs units.

Some simple operations are available in the work sheet. All of them can be reached by window menu or popup menu (right mouse button) Here they are:

- *Load...* Load file content into the work sheet. Previous content will be lost.
- *Save...* Save work sheet content into the file. You are encouraged to do it periodically during the session.
- *Delete* Delete current row (normally highlighted, but not necessary). Program re-numerates all the targets and updates map views.
- *Undo* Undo last deletion. Up to 50 undo calls are available.

9.4 Option of mass estimation

In case of known κ, J_{rem}, and a given vector of total magnetisation an attempt to estimate the mass of the body can be made. MagPick does it automatically after each inversion. One should understand that mass estimations can be incorrect in many cases due to the difference between assumed and real magnetic properties of the object. In some cases the problem can not be solved mathematically (see below). Nevertheless MagPick will always give two values for the mass which correspond two roots in a square equation. In case the equation can not be solved the value of extremum of the quadratic function replaces both roots and a message is printed on the console (Unix version). In the last case a predicted value of $\vec{J}$ can be calculated and compared with the MagPick estimation. The relative difference (in %) arrears in the column *Discr.*.

9.5 Automatic estimation of magnetic sources.

You should note that the estimation procedure requires good deal of manual work. It involves selection of the area of interest; setting pick(s) (by hand or by some simple procedures as rectangular pick or even autopick); running estimation and inspection of results. This should be repeated for all points of interest.

To avoid this MagPick has a simplified routine which allows it to interpret all anomalies at once. It should be noted that the results of such an interpretations are still to be inspected. The procedure is available under *Inversion / Run batch*. Its parameters are identical to the previous one described in the inversion but instead of treating all data in the window MagPick does the following:

- Goes pick by pick. For each pick it selects only the data around it.
- Applies inversion for this pick. Inspects a misfit. If it is more than user specified value result is rejected; if less than user specified value result is appended into worksheet.
- Repeats these steps for every pick.

As you see this method does not allow you to estimate a few magnetic sources simultaneously.

10 Implementation of the inversion in magpick

To find magnetic sources, MagPick uses a simple form of inversion based on a model represented by set of dipoles. Mathematical expressions for the field produced by such a source are well-known and have a simple form. This allows one to construct an effective inversion algorithm. Here is the outline of some basic features of forward and inverse problems as they have been implemented inside MagPick. It is important to understand that MagPick does not take into account demagnetisation effects which can have significant value in case of iron objects.

10.1 Solution of forward problem.

It is known that a magnetic field can be expressed as a combination of second derivatives of the gravity potential. Which in the case of uniform magnetized sphere of unit mass has the following simplest form:

$$V = \frac{1}{\sqrt{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2}}$$

Here x_0, y_0, z_0 are coordinates of the center of the sphere, and x, y, z are coordinates of the observation point. If the sphere has a magnetic moment with components J_x, J_y, J_z magnetic field can be expressed as:

$$X = V_{xx}J_x + V_{xy}J_y + V_{xz}J_z$$
$$Y = V_{xy}J_x + V_{yy}J_y + V_{yz}J_z$$
$$Z = V_{xz}J_x + V_{yz}J_y + V_{zz}J_z$$

where V_{xy} denotes the partial derivatives of potential. X, Y, Z are horizontal and vertical components of the magnetic field. In case of full vector measurements these values have to be projected on direction of the Earth's magnetic field. Considering D - declination of the Earth's field, and I - inclination formula for full field can be written as:

$$T = X\cos I\cos D + Y\cos I\sin D + Z\sin I$$

Note that vector $\vec{J}$ can has an arbitrary direction and value. Thus to solve the forward task in the general case three geometrical and three amplitude parameters should be known for each dipole.

The magnetic moment can be considered as a sum of induced and remanent magnetization. In this case we know these values per volume $\vec{J}$ can be expressed as:

$$\vec{J} = v\kappa F\vec{n}_{earth} + J_{rem}v\vec{n}_{rem}10^5$$

κ - magnetic susceptibility per volume, cgs units.
F - magnitude of Earth's magnetic field, nT.
$\vec{n}_{earth}$ - unit vector in parallel to the Earth field.
J_{rem} - remanent magnetisation of the sphere, gauss.
$\vec{n}_{rem}$ - unit vector parallel to direction of remanent magnetisation
v - volume of the body, cm^3.
In the case all distances are measured in cm then κ in cgs units, J_{rem} in gauss and $\vec{J}$ in nTesla.

10.2 Basic inversion

To estimate position and magnitude of the source we have to model the observed magnetic field. Mathematically it means that function

$$\sum_{i=0}^{N} \mid T^o(\vec{r}_i^o) - T^c(\vec{r}_i^o, \vec{r}_1, ...\vec{r}_M, \vec{J}_1, ...\vec{J}_M) \mid^2$$

has to be minimized. Here is:
T^o - observed magnetic field;
$\vec{r}_i^o$ - points of observations, total number N; in case of the grid interpretation they are nodes of grid; in case of profile interpretation they are points of actual measurements;
T^c - expression of the magnetic field from M magnetic dipoles.

Generally the problem is non-linear but can be divided in two steps: a linear step to find $\vec{J}$ and a non-linear step to estimate positions. The flow of execution is the next. First fix the positions of dipoles and estimate $\vec{J}$. Then fix $\vec{J}$ and improve the positions and so on.

Thus J_i are linear parameters and can be found in one step by inversion of the matrix:

$$\mathbf{A}\vec{J} = \vec{T}$$

In the case of one dipole **A** is the matrix $3 \times N$, where N is number of data points, and $\vec{T}$ is data itself. Columns of **A** have meaning of the magnetic field calculated from the dipole with a unit magnetic moment (sequentially along X, Y, Z axis). This task is overdetermined and $\vec{J}$ can be found by simple least-squares method. MagPick uses this in the modification of the singular value decomposition.

In most cases there is a significant background (regional field) in the observed field which can disturb or even completely destroy the solution. To avoid that linear function can be fit simultaneously with estimation of $\vec{J}$:

$$T = Ax + By + C$$

or in the case of a profile based interpretation where Z values are important

$$T(x) = Ax + By + C + Dz + Ez^2$$

There is total of $3 \times M + 3$ or $3 \times M + 5$ variables for the linear step which does not require iterations and can be solved at once.

To estimate position of the dipole, the non-linear problem has to be solved. MagPick employs the simple Newton's method to estimate $x_0, y_0.z_0$. Given an initial guess and magnetization magnetic field can be calculated. The discrepancy between observed and calculated field can be expanded into the Taylor's series, truncated to the linear terms and written as the following equation:

$$\frac{\partial T(x_0, y_0, z_0)}{\partial (x_0, y_0, z_0)} \vec{\delta} d = \vec{T}_{obs} - \vec{T}_{calc}$$

where $\frac{\partial T(x_0, y_0, z_0)}{\partial (x_0, y_0, z_0)}$ is the matrix of partial derivatives of T at the point of the initial guess. δd is the correction of the position and $\vec{T}_{calc}$ is the field calculated at the point of initial guess. Then the new improved position can be found as:

$$\vec{r}_1 = \vec{r}_0 + \vec{\delta}$$

The magnetization vector has to be estimated again using a new position. The process has to be repeated till the discrepancy between the observed and calculated field becomes small and stable.

10.3 Estimation of susceptibility and remanent magnetisation

For mass estimation, susceptibility and remanent magnetization of the body must be known. They can be estimated if at least two sets of data with different orientations of the object were measured. For each orientation total magnetization of the body can be estimated as it is described above. It means two vectors $\vec{J}^1$ and $\vec{J}^2$ are know. Both of them have an induced and remanent part:

$$\begin{aligned} \vec{J}^1 &= v\kappa F \vec{n}_{earth} + J_{rem} v \vec{n}^1_{rem} \\ \vec{J}^2 &= v\kappa F \vec{n}_{earth} + J_{rem} v \vec{n}^2_{rem} \end{aligned}$$

Here $\vec{n}^i_{rem}$ is the unit vector along the remanent part which has to satisfy norm condition $|\vec{n}^i_{rem}| = 1$. [5] Together with norm conditions we have 8 equations and 8 variables: $\kappa, J_{rem}, \vec{n}^1_{rem}, \vec{n}^2_{rem}$. This system can be solved as the following

[5] Here and below multiplier 10^5 is included into J_{rem}

$$\begin{aligned} \kappa &= \frac{\vec{J^2}^2 - \vec{J^1}^2}{2v[(\vec{J^2} \cdot \vec{n}_{earth}) - (\vec{J^1} \cdot \vec{n}_{earth})]} \\ J_{rem} &= \frac{1}{v}\sqrt{\vec{J^1}^2 + v^2\kappa^2 - 2v\kappa(\vec{J^1} \cdot \vec{n}_{earth})} \end{aligned}$$

The periods ($\cdot$) in the equations denote scalar multiplication. This is the way susceptibility and remanent magnetisation can be estimated.

10.4 Mass estimation.

Given the total magnetization of the sphere, κ, and J_{rem} one could estimate the mass (or volume) of the body. The following system must be solved:

$$\vec{J} = v\kappa F\vec{n}_{earth} + J_{rem}v\vec{n}_{rem}$$

Here is the same norm condition as above: $|\vec{n}_{rem}| = 1$. There are 4 equations and 4 variables have to be estimated. These are volume of the body v and three components of the remanent vector direction. This equation can be reduced to:

$$(\kappa^2 - J_{rem}^2)v^2 - 2\kappa(\vec{J} \cdot \vec{n}_{earth})v + J^2 = 0$$

This is a square equation for v and can have positive or negative roots. It also may not have any roots. In the case when there are no roots the v value, which coincides with extremum, might be taken as an approximation of the root. It is clear that negative roots do not have physical meaning.

It has to be made clear that this approach does not provide a good mass estimation for all cases. This is due to possible large variations in the magnetic properties of the different metalic objects. In the case of two positive roots no assumption can be made which one is correct.

11 Export to the CAD and other graphic programs

11.1 Export to the AutoCAD(TM) and compatible software via DXF file

Magpick is capable of preparinf an ASCII DXF file which can include the following elements:

- Coordinate grid with axis annotation and general title. The default font is used, and the grid steps are the same as on the screen. Grid labels can be formated in meters or in degrees, minutes and seconds.
- Magnetic field contour map as lines (contour plot option). The slow contour method is recommended because it allows inclusion of labels. However the fast contouring method can be used.
- Profile XY positions with direction pointers.
- Profile stack plot.

- User's picks, results of inversion, polygon and pointer.
- Additional drawings such as lines, polygons and points. However clip is not included.

All of the above elements reside on different AutoCAD layers. Properties of each layer such as name, color, and line style are user selectable. Each drawing can have its color defined by layer or directly thus allowing the AutoCAD user to change the color of all drawings on the layer at once.

The DXF file is in compliance with DXF 2.5 specification and works with the following CAD systems: Autocad release 12 and 13, ItelliCAD from CADopia, AutoDesk Volo View Express (viewer for DXF and DWG files), TurboCAD 2D, and FastCad DWG/DXF viewer. The DXF file does not contain any AutoCAD variables, only line style and layers definition tables and entities.

To match RGB colors in MagPick to AutoCAD pens a standard AutoCAD palette is used. In some cases it might result in different color in AutoCAD as compared with MagPick. However most af the colors are transferred without distortions.

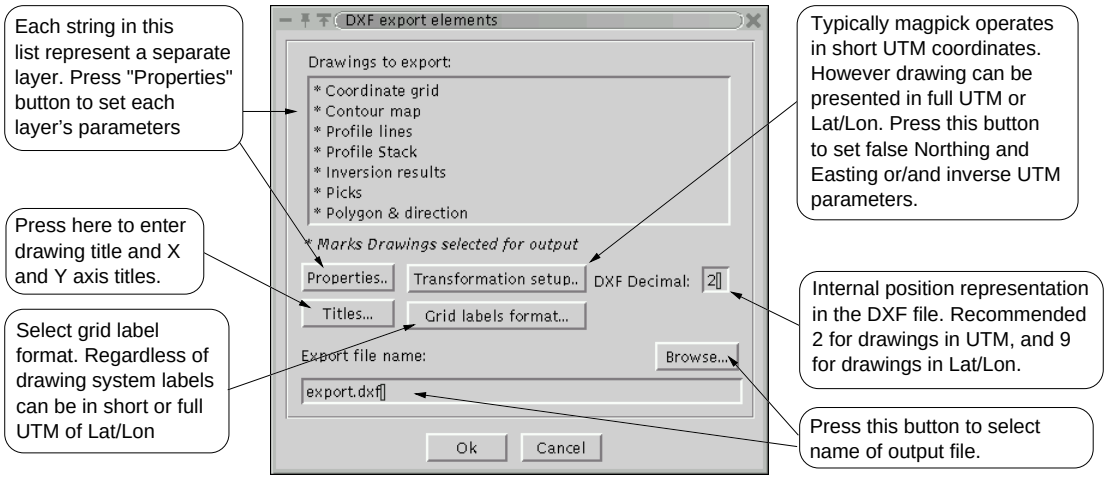
Each string in this list represent a separate layer. Press "Properties" button to set each layer's parameters
Press here to enter drawing title and X and Y axis titles.
Select grid label format. Regardless of drawing system labels can be in short or full UTM of Lat/Lon
DXF export elements
Drawings to export:
* Coordinate grid
* Contour map
* Profile lines
* Profile Stack
* Inversion results
* Picks
* Polygon & direction
* Marks Drawings selected for output
Properties..
Transformation setup..
DXF Decimal:
2
Titles...
Grid labels format...
Export file name:
Browse...
export.dxf
Ok
Cancel
Typically magpick operates in short UTM coordinates. However drawing can be presented in full UTM or Lat/Lon. Press this button to set false Northing and Easting or/and inverse UTM parameters.
Internal position representation in the DXF file. Recommended 2 for drawings in UTM, and 9 for drawings in Lat/Lon.
Press this button to select name of output file.

Figure 30: DXF export dialog

DXF export is available in the grid window under *File/Picture export.../DXF*. Look at figure 30. It presents the DXF export dialog box. Each layer is represented by the string in the list box. Star "*" means that the layer is selected for output. The absence of "*" means that the corresponding layer won't be included in the drawing. To edit each layers properties select them in the list box and push the button *Properties...*. The dialog box shown on figure 31 is displayed. Here the user can alter the following elements:

- Enable or disable layer. If the layer is disabled its definition and all entities are omitted in the DXF file. If layer is enabled but there are no entities (if user did not request to draw them in *Common parameters* dialog 1) then the layer is presented in DXF table but there are to entities. If the layer is enabled and its entities are drawn in MagPick then they also are drawn in the DXF file.
- Layer name. MagPick will assign names itself, however the user can change them. (Do not enter same name for different layers!)
- Line style. MagPick uses the following convention to code line style: $digit1, digit2, \ldots$ where $digit$ is length of the line dash. If $digit > 0$ then line is drawn (pen down) if $digit < 0$ the

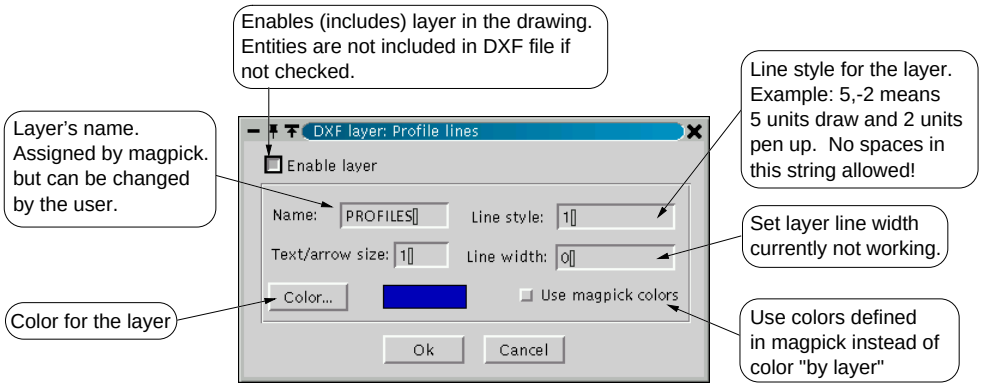
Enables (includes) layer in the drawing. Entities are not included in DXF file if not checked.
Line style for the layer. Example: 5,-2 means 5 units draw and 2 units pen up. No spaces in this string allowed!
Layer's name. Assigned by magpick. but can be changed by the user.
DXF layer: Profile lines
Enable layer
Name:
PROFILES
Line style:
1
Text/arrow size:
1
Line width:
0
Color...
Use magpick colors
Ok
Cancel
Set layer line width currently not working.
Color for the layer
Use colors defined in magpick instead of color "by layer"

Figure 31: DXF layer properties

pen moves without drawing the line. Example: 5,-2 produces line 2 meter gaps each 5 meters. Spaces are not allowed in the line style definition.

- Text/arrow size. In some cases these values overwrite the values defined in MagPick. For example the program uses the size defined here to label grid lines or draw profile direction arrows. However the stack label text and arrow sizes are defined in 5.

- Line width. Presently not used.

- Color. Default color for the layer. If the *User magpick colors* box is not checked all layer entities have color ”by layer”

- User MagPick colors. If this box is not checked all layer entities have color ”by layer”. If checked, then the color is defined explicitely for each entity.

Magpick works in the short form of UTM projection. Therefore all sizes above (line style, text and arrow) are in meters. If user requests transformation (for example inverse UTM to present drawing in latitude and longitude - see below) these values are still in meters; program will automatically recalculate appropriate sizes in degrees.

The user can enable *transformation* while preparing the DXF file. The typical case is to have the DXF drawing in full UTM coordinates while internal MagPick picture is in short UTM (just add Northing and Easting values). Another case could be when the user wants to have a drawing in latitude and longitude.

To use this feature the user can press *Transformation setup...* button. This allows the program to transform coordinates in two ways:

- Linear transformation. $X_{magpick}, Y_{magpick}$ coordinates are transformed as $X_{drawing} = X_{scale} \times X_{magpick} + X_{offset}$ and $Y_{drawing} = Y_{scale} \times Y_{magpick} + Y_{offset}$. For typical short to full UTM transformation $X_{scale} = Y_{scale} = 1$.

- Inverse UTM transformation. This should be enabled only if the user wants to present a drawing in Latitude and Longitude. Attention should be paid to set correct UTM parameters. *If both linear and inverse UTM transformations are requested program first performs linear and then inverse UTM*. Note that false Northing and Easting are parts of UTM parameters (see figure 24).

Note that the text and arrow size should be set in the MagPick coordinate system. The program recalculates sizes in the transformed system automatically.

To specify general title of the plot and axis titles press *Titles*. Remove any text if you don't want titles. All titles are plotted on the same layer as coordinate grid, with slightly increased text hight.

Grid labels format controls how labels are printed. The user can choose decimal degrees, degrees and minutes, or degrees, minutes and seconds. The latter two make sense if *Inverse UTM* is enabled in *Grid labels* dialog. Regardless of which one is choosen, the drawing coordinate system labels can be presented in UTM or latitude and longitude.

Figure 32 shows a contour plot exported into a DXF file. To obtain the contour labels "slow contours" should be used (see 2). MagPick uses the text hight defined for the layer and fits labels into the space defined in the contour dialog box (refiso). Due to this operation labels have different sizes (the most obvious example is contour 0nT)

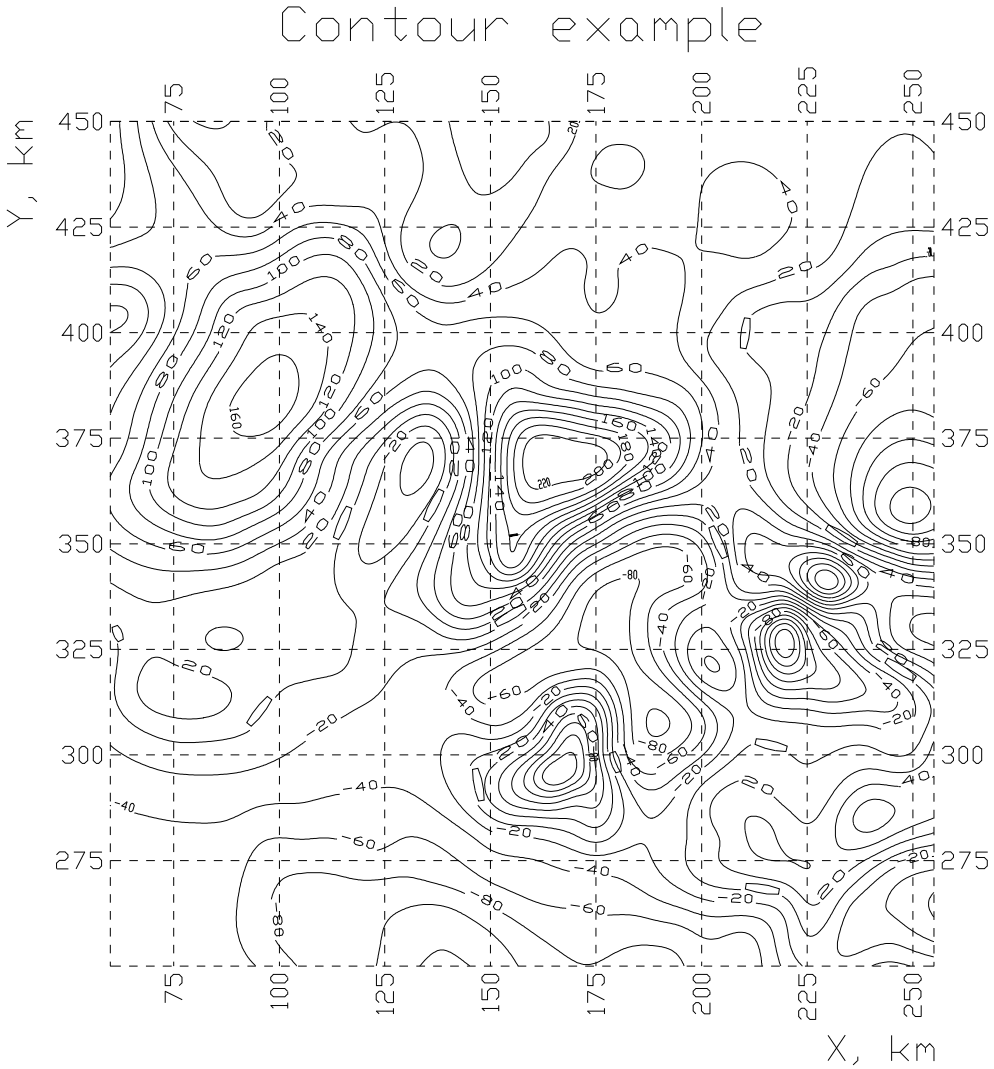

Figure 32: Example of DXF contour plot

On figure 33 you can see result of export for stack plot. If you are viewing this manual with Adobe Acrobat zoom into the picture to see small details. This drawing also includes line file (magenta) (see *Drawing and clipping on top of the map* 1)

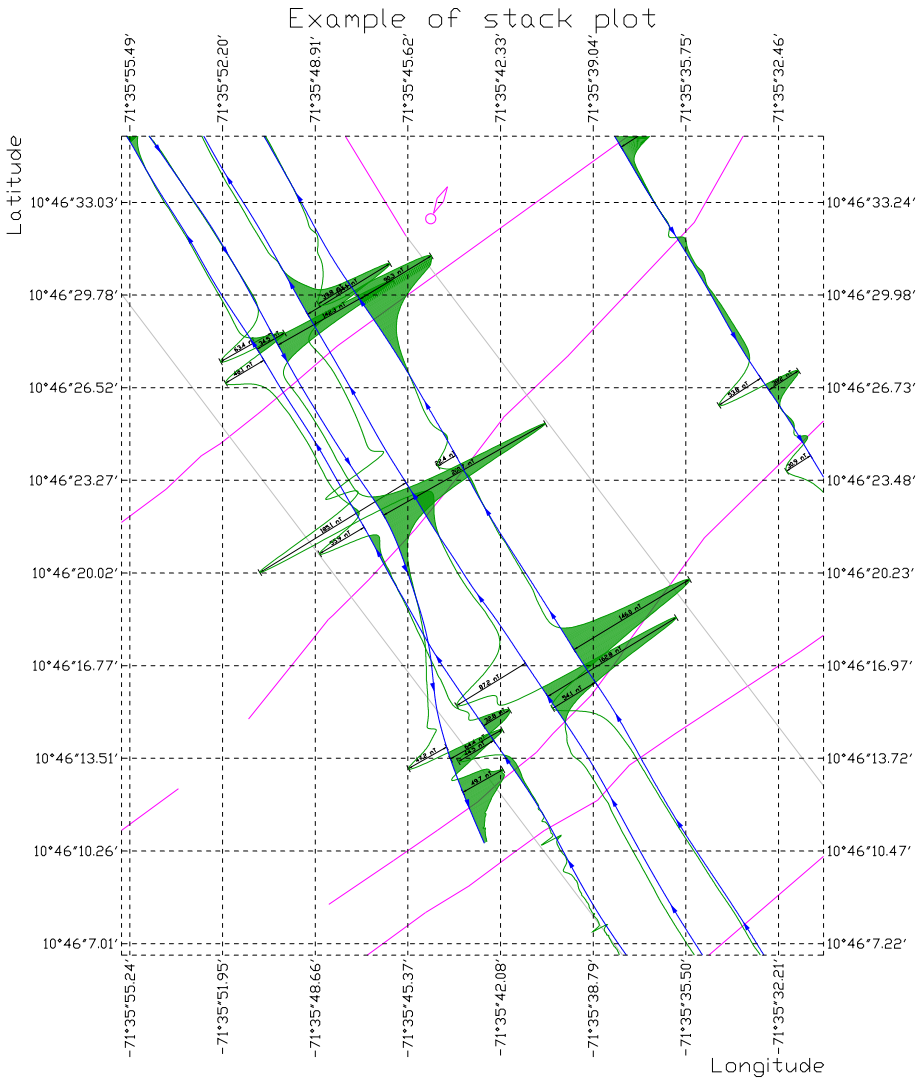

Figure 33: DXF stack plot with magpick.

12 Tutorial

12.1 View grid files with MagPick.

Goal: Show how grid information presented in SURFER ASCII format can be loaded and viewed with MagPick. After this lesson you should be able to load grid data into the program, adjust size of the view, pick appropriate color scheme, and the coordinate mesh. You will learn how to zoom parts of your map to see details with Magpick.
Files: for that lesson we take file `helens2.grd` which comes with the standard SURFER distribution (if you are using SURFER 7 convert this file in ASCII grid or SURFER 6 binary format using SURFER).

1. **Check initial state.**

   Start magpick (from Windows explorer, shortcut or command prompt - this does not make any difference. Go to *Options/Size*. Make sure that *X-size, cell* and *Y-size, cell* are set to 1. These

are hight and width, in pixels, of one cell of your grid data on the screen.

Let *Zoom* be something like 2 or 4, and check *autoscale on zoom*. Press ”Ok”.

Go to *Options/Settings. Common parameters* dialog pops on the screen. Uncheck here all check boxes except *Autoscale* and *Colored map*. Note that when you check *Colored map* another dialog appears. In this dialog select *Drawing mode: Simple color map* and press Ok.

Press button *Change palette* , choose *Uniform*, press Ok. The uniform palette preview appears; make sure that the palette number is 34 and the *Equalize colors* dialog box is checked.

Press Ok to close this box and once more to close *Common parameters*.

You are now ready to load the data.

2. **Pick and load the file. Inspect result.**

   Go to *File/Open* and pick file `helens2.grd`. After reading and color equalization, a colored map appears on the screen.

   Check what was loaded. Go to *Options/Info*. You can see all the geometrical parameters of the loaded grid.

3. **Change geometrical parameters of the view.**

   Let’s play with it a little to learn how it works. Our main tool will be *Common parameters* dialog available under *Options/Settings* menu. We proceed as folows: call this dialog, change something, replot picture by pressing Ok.

   Call *Options/Settings...*, check *Show x grid* and *Show y grid*. Set *X:* and *Y:* values as 2000 (these are meters, I believe). Press Ok. Now we have coordinate mesh.

   Look at the status bar in the main window (at the bottom). You will see a string which starts with the word *First* and then 3 numbers. These numbers are X, Y, and Z (data) values in the cell where the mouse cursor currently is. When you move the mouse, these numbers are changing. You can check correctness of the coordinate mesh with a mouse this way.

   You may note that these values are not exactly the same as mesh labels. This is due to the finite size of one cell (which occupies now exactly one pixel on the screen).

   Now we would like to change this: for example each pixel should occupy area of 3×3 pixels on the screen. Therefore the picture will be increased 3 times. Go to *Options/Size*; set X,cell and Y, cell sizes as 3, and answer ”Yes” to the question which appears.

   The picture is larger! You can scroll it with scroll bars (these are not always correct under Windows) but here is a trick: hold right mouse button and drag.

   A bit more: go to *Option/Size...* and set X cell size as 5, and Y cell size as 1. Press Ok. Notice the difference.

   An important lesson can be learn here: if your grid cell size in the file is 5×5 meters, in order to see the picture undistorted you must choose sizes like 1×1, 2×2, 3×3.. Do not choose sizes where X cell and Y cell are different. If your real grid cell size is 2.5×5 meters the undistorted picture will appear if your choose 1×2, 2×4, etc.

   Note that unfortunately not every grid cell size can be viewed undistorted. Therefore grid your data preferably with equal steps along X and Y.

   Now go back to the 1×1 size.

4. **Zoom a picture.**

   We just have learned how to zoom all the picture. Very often all what we need is to see some part of the big map. Here is how you can do it

   - Go t *Edit/Zoom*; the mouse cursor changes its shape.
   - Press the left button and drag; release the button.

   Part of the map appears in a new window. Note that if *autoscale on zoom* is checked (when old window is active) the color scale in this new window automatically adjusts to the local (in the window) minimum and maximum of the data. Therefore you have your full color scale in a narrower range and can see your data better.

   This new window can be zoomed again and again. There is no limit on the zoom number.

   Unfortunately **MagPick** has some problems with zooming near the borders :-(.

5. **Change data color mapping.**

   Go to *Common parameters* again. Here we will learn how to change the color scale.

   The *Autoscale* box is checked now. The two grayed numbers above it are minimum and maximum values of your data. Uncheck it. The fields above become available. Set the minimum to 1500, and maximum to 2000.

   All the colored range now is mapped to 1500:2500, and you can see only the top of the mountain. All that is less then 1500 is mapped with blue. All that is more that 2500 is mapped with red. Intermediate colors are in between blue and red.

   Now lets look at another kind of mapping. Say, we set range 0:500. All what above is (or below) this range will be wrapped to this range. Therefore the value 510 will appear as 10 (and value 1010 too). This method is useful for viewing of magnetic maps which have some points with extremely high values.

   MagPick employs this method using the *Wrap color scale* check box. Set minimum value as 0 and maximum as 500, check the box, press Ok, and see what happens.

   It looks now as a rainbow. The data going up in color changes from blue to red. When it reaches 500 it becomes blue again and so on.

   Now uncheck this box and check *Autoscale* again.

6. **Color palette.**

   MagPick implements two methods of color mapping: linear and gradient. Linear means that the color range simply gets mapped to your data range. There are 41 pre-defined palettes in **MagPick**. To see them all, go to *Common parameters* and press *Change palette*. Choose *Uniform*, set palette number you like, see how the picture changes (after you pressed Ok in *Common parameters* dialog).

   Mapping of data into color is linear if *Equalize colors* box is unchecked and non-linear based on your data distribution if *Equalize colors* box is checked. This last method provides a coloring where each color occupies the same area on the screen as any other color. Therefore the picture is much richer. Try for example with palette 34. Use with color equalization and without. See the difference.

A second method, gradient palette, gives you more control on the color you wish to have. It does not provide color equalization. Go to *Change palette/Gradient*. You are seeing the gradient palette with control points. You are free to move these points, change their colors, and values with a mouse. Press the right mouse button to see a menu. There is a pre-defined set of palettes for your convenience. For example, choose *Land and Sea* and then choose *Revert colors* . The gray is large. To reduce it move the second from the top color point up. You can move other points as well to provide the same interval for each color. Press Ok now and see what happens.

7. **Advanced mapping techniques.**

   The mapping methods include shaded relief and illuminated color map. The last may as good for magnetic data than for topography. It takes a considerable time to calculate and plot the picture.

   Let's start with shaded relief (I assume that `helens2.grd` is loaded.) Go to *Options/Settings...*, press *Change palette*, and make sure that*Uniform* has been set. Now click on *Colored map* check box. You should click once or twice to invoke dialog box responsible for mapping. Choose *Shaded relief* and set light azimuth 315, elevation 25 (see as sun is rotating). Set data scale as 5. This last value will be different for your real data and you have to try few numbers to find the best value

   You can see now a black and white "steel" picture with shadows.

   Now go to the same place and set *Color illuminated map*. Press *Change palette* and set Uniform 34. Press Ok.

   See how long it takes now. But you end up with a nice view. Try the same with "gradient/land and sea" palette (as it was shown above).

8. **Make your map nice - add contours (isolines).**

   The simplest way to do it is go to *Options/settings* and invoke *contours* dialog box by clicking on *isolines* check box. Here check *Automatic; Total: 50 Fast drawing.* This means that your data interval will be divided into 50 contours. *Fast drawing* means that no labels are available for the contours, but drawing is somewhat faster. I found this useful in some cases for a magnetic field. If you have a lot of lines it can give a clearer picture than shaded relief or color map.

   Press Ok. See what happens.

   Now for a slower way but with labels go to the contours menu as before, check *Fixed values*, type *Min:* 0, *Max:* 2500, *Interval* 100. Press *Calculate*. See that levels 0, 100, 200 ... 2500 are created. Now uncheck *Fast drawing* and check *Label contours*. Set the distance between labels as 4000. This means you want your lines annotated every 4000 units along the contour. Set label length as 1000. This means there will be a gap in the contour of 1000 units to fit annotation text. Press Ok.

   In the current program version the progress indicator is not clear for this kind of drawing; you have to wait about 1.5 minutes to have job done (for Pentium 200 MHz PC :-()

9. **Printing your map.**

Magpick printing capabilities are limited. They allow you to have at least a hard copy of what you did. The printed picture will always be fitted to your paper. Therefore it is impossible to choose the exact scale you want (this may be be changed in future versions).

Here is how to print. Go to *Options/Title*; to set X, Y titles (Y title never appears under MS Windows) and general text above the plot. Also choose the font size in 1/72 inch units. I recommend something like 10 (you may pick different values depending on results). Press close.

Now go to *Preview*. A blank page will appear on the screen (this is one of the problems to be solved). This is acceptable, press *Print*; setup your printer if need (page orientation, size, etc). Press Ok. The job is going to be printed. Take the page from the printer when it is ready.

MagPick produces big print jobs (mostly under MS Windows). You should have enough memory to spool it. For the task you just did (`helens2.grd` with contours) it used 11.8 MB.

Questions:

- How to make magpick do not plot any color map ?

12.2 Load profile information into MagPick.

Goal: Show how the profile data (file with space or tab separated columns) can be loaded into **MagPick**. You will be able to inspect the data as linear graphs elongated along local X, Y or profile direction itself. After this lesson you should be able to use MagPick as a simple viewer for profile data.
Files: We need files `g-858m.dat` and `g-858g.dat` which were generously provided by Paul Kot. These are result of an export from Magmap Geometrics program and represent magnetic data acquired with G-858 hand held magnetometer. Two different techniques were used for positioning, ground marks (file `g-858m.dat`) and differential GPS receiver (`g-858g.dat`). Therefore positions in first file are in some ”local” coordinate system but in second file they are in California grid.

1. **Loading one profile data from one file.**

   Start **MagPick**, go to *File/Profiles/Simple Load*. Press button *Add* and choose file `g-858m.dat`. This file has a header string with names of the columns, therefore you can see the number of the column and its name (if the file does not have this header only the column numbers show up). We need to decide which columns represent X, Y, and magnetic field. File has 9 columns. These are X, Y, TOP_RDG (magnetic field for top sensor), BOTTOM_RDG (for bottom sensor), VRT_GRAD (difference between them), TIME, DATE, LINE (logical line assigned by operator), and MARK.

   X is the x-axis, and Y is y-axis. Select them in the list boxes *X:* and *Y:* Now we have to select the data. Let’s take a bottom reading - select BOTTOM_RDG (4) in list box *Data:*.

   The profile view on the map (as XY curve) can be active (if selected by operator and being viewed in a separate window) or inactive (not selected and not viewed). It is makes sense to have different colors for these two conditions. Names of the colors you can change under *Active color* and *Inactive color*. Let it be RED (active) and BLUE (inactive).

   Press Ok. *Create the profile description* dialog closes and you can see that a new string appears in the list box.

Press Ok. Profile data is being loaded as X,Y, magnetic field. Finally MagPick reports: 1 profile loaded.

If you are familiar with magnetic survey design this may seem strange. File `g-858m.dat` has 51 lines. The problem is you did not tell MagPick how to distinguish data between lines. We will now go over how to correct this problem.

2. **Loading several profiles (lines) from one data file.**

   Go again to *File/Profiles/Simple Load*, press *Add* and choose file `g-858m.dat`. You see the *Split:*. Here you can specify how **MagPick** is going to recognize end of individual line. It can do it automatically by finding gaps in your position data. Select *Distance* and specify the length of the gap under *Distance* enter field to use this feature. If data file has a special column to mark line change **MagPick** can use this column for line separation. Change in content of this column indicates line change. For example to mark line 1 you can have ”0” in line column, to mark line 2 - ”1” and to mark line 3 - ”0” again.

   Go to *Split:* and select LINE. Press Ok, and press Ok once more.

   A question appears: *Append to previous profile list?* The problem is that we already have load some profile data. Now **MagPick** wants to know do we need keep the data in memory or discard it. Answer *No* and the old profile will be taken out. Please note for future: if any views of old profile data are currently opened, **MagPick** will not discard old data. The loading operation will fail until you close all profile windows.

   Now **MagPick** shows that it has loaded the 51 profile. Press Ok.

3. **Viewing of profile data.**

   Go to *File/New* and choose *Profile view* in the dialog box. You will see just an empty screen with a red vertical line on the right side.

   This is because by default MagPick shows your data as T(x) (here T denotes the data, x - x-axis). But lines in `g-858m.dat` are elongated along Y. To the change view to T(y) go to *Parameters/Settings* and select *Type: Along Y* (list box at the left bottom corner of the dialog) Press Ok. Now you can see correct graph of the data as function of x-axis.

   The status bar at the bottom of the window shows the type of view T(y) It also shows Y and T values at the current mouse location.

   Go to *Parameters/Settings* again and set *Type: Along profile* Now the horizontal axis shows the distance along the line (line may not be straight). This distance is always positive and starts with 0. Checkbox *Shrink to canvas* is responsible for the display method. If it is checked then *Y size:* and *X size:* (vertical and horizontal sizes of the canvas) stay constant when you change your profile. The profile data gets scaled to these fixed sizes. If it is not checked, then *T scale*, and *X scale* parameters are used to find the appropriate size of the canvas to accommodate the data. In this last case vertical (and horizontal) scales of the data stay constant when you change profiles. You can see difference between them in the same scale.

   Set *Y size:* as 500 and *X size:* as 1000. Notice this is how we can zoom data.

   We also can zoom data the same way we did for maps. Go to *Edit/Zoom*. Then press the left button and drag mouse to select area. Instead of creating new window graphs are zoomed in the same window. To ”unzoom” just go to *Edit/Redraw*. This kind of zooming works best when ”shrink” is checked.

4. **Browsing profile data.**

   There were 51 lines but we see just only one. To see other lines go to *File/Browse*. The modaless dialog window appears with all your lines (with string numbers from the file) Press buttons >> and <<; picture will change. (Fast sequencing of these buttons can cause crash under X-windows) You also can select data directly from the list box (by mouse).

   Now we will show how "shrink" works: select first line and go to *Parameters/Settings*. Uncheck *shrink to canvas* and set *T scale:* as 1 and *X scale:* as 0.1. Press Ok and go to profile browser. Go thru profiles again. Dou you see a difference? Data is always presented in the same scale, therefore it is easy to recognize large and small anomalies.

   Check "shrink" again. You can have as many profile windows as you wish. Just go to *File/New* to create them.

5. **Add another file to the profile list**

   We have file `g-858g.dat` which is worth looking at. Create new (empty) grid view (we need it just to access *File/Profiles/Simple Load*.) Select `g-858g.dat` now. Choose split by LINE, and data as BOTTOM_RDG. Press Ok, and press Ok again. Answer "Yes" to *Append to previous profile list?*. The total number of profiles loaded is 102 now. Create a new profile view (the old one does not know you loaded new data) Now you have both - second one has very large numbers as X, Y coordinates This creates a some problem that we will describe later.

   You can browse two files with profile data now. You can have as many files as you need.

6. **Saving file list for future use.**

   What happens if you have 200 files? Add them all one by one every time you need to load information? No. When you go to *File/Profiles/Simple Load* you have a check box *Save as profile list* If this box is checked, **MagPick** will ask you to save the list of your profiles into a separate file. For example load `g-858g.dat`. Check the box; press Ok; enter file name `g-858g.lst`

   Now exit MagPick and start it again. Go to *File/Profiles/Load list* Select file `g-858g.lst`. The result will be the same as with a simple load but we do not need to go through all the pevious steps again.

   You also can create profile list file by hand using you favorite ASCII editor, small shell script or your program. Note that profile list file gives you more control on data loading. For example, **MagPick** can accept few data sets in one file, but this feature can accessed only using profile lists.

12.3 Putting things together: map and profile data.

Goal: MagPick is designed to work with two types of data: map (grid) data and profile data. Here we will be given profile data as initial information. We will grid the data by **MagPick**. Then we will load the created map into **MagPick** to see them together. For a better understanding of the field structure we will present the profile data as a stack plot on top of the magnetic map. Some optional learning material is included here to show how any geometrical information can be included in the view. After completion of this part you should be familiar with the creation of magnetic maps using **MagPick**.
Files: File `g-858m.dat` is the only one we need here.

1. **Load profile data.**

Start MagPick. Go to *File/Profiles/Simple Load*. Press the button *Add* and choose file `g-858m.dat`. Set the following:

- *Split:* 8 LINE
- *X:* 1 X
- *Y:* 2 Y
- *Data:* 4 BOTTON_RDG
- *Active color:* RED
- *Inactive color:* BLUE

Press Ok. A new string appears in the list box. Check the button *Save as profile list.* Check that *False Easting* and *False Northing* are zero. Press OK. The file save dialog pops on the screen. Enter the file name `g-858m.lst`. Press OK. MagPick indicates that 51 profiles (lines) were loaded. Press OK. You have read all your data into MagPick.

2. **Loaded grid data.**

   Go to *File/New* and choose *Profile view* in the dialog. What you see now was discussed above. Go to *File/Interpolate grid/Splines*. The dialog box *Interpolation parameters* with many fields appears on the screen. Here what to do next:

   - Under *X parameters* check *Data limits*. This means that the horizontal extent of your grid will be taken in accordance with minimum and maximum values of the X coordinate in the data.
   - Under *X parameters* set an interval 0.25 This is your grid cell size along the X axis in the grid we are going to interpolate.
   - Under *Y parameters* check *Data limits*. This means that the vertical extent of your grid will be taken in accordance with minimum and maximum values of Y coordinate in the data.
   - Under *Y parameters* set interval 0.25. This is your grid cell size along the Y axis in the grid we are going to interpolate.
   - Set *Low constrain* as *by min data value* and *High constrain* as *by max data value*. This means that the interpolated grid can not have values less or more than initial data set.
   - Set *Tension* as 0.25 and *Format* as *GS ASCII* (the last means Golden Software ASCII)
   - Set *Iterations:* to 250. It should be enough for most cases.
   - Set *Convergence limit* 0.
   - Press *Output file...* and enter name `g-858m.grd`. This is where the result of the interpolation will be stored (as a grid file).
   - Advanced: read article *Smith and Wessel, Geophysics, 3, 293-305, 1990)* to learn more about this interpolation method.

   Press Ok and wait until the program completes interpolation. You are seeing the progress dialog *Gridding is working...* which shows the iteration number and discrepancy for the current step. It can take from several minutes to complete interpolation.

3. **View interpolated map**

   Go now to *File/New* and choose *Grid view*. The empty window appears. Check *Options/Size*; set X and Y sizes as 1. Then check *Options/Settings*; Here is what to do next:

   - Check *Autoscale.*
   - Check *Show x grid* and *Show y grid*; Set *X: Y:* as 10.
   - Uncheck *Snap to grid* and *Contours*; we do not need this checked for now.
   - Check *Show profiles*; in the configuration dialog *Profile plot parameters* uncheck *Show profile direction* and *Plot stack profile*; press OK.
   - Check *Color map*; in configuration dialog *Color map draw mode* set *Drawing mode:* as *Simple color map* and press OK.
   - Press *Change palette...*; select *Uniform*, choose number 33 and check *Equalize colors*

   We are ready now to load our file. Please note that your are free to adjust settings above anytime after the file is loaded. We did it now just to insure proper initial appearance of the picture.

   Now go to *File/Open* and pick `g-858m.grd`. You have two windows on the screen now; one with profile data and another a magnetic map with blue vertical lines which shows profiles position.

4. **Simple profile - map interaction**

   Go now to the profile view and change horizontal axis - *Parameters/Settings* then *Type: Along Y*. You can see a field that was taken along Y. Note that the right profile line on the map view is highlighted by red. This is the same line we see in the profile view window. Again in the profile view go to *File/Browse*; in *Profile browser* dialog press button marked >>. You can see that a red line on the map view is moving to the left and field in the profile view window changes. You know exactly which profile you are looking at. Now in the map view go to *Edit/Pick profile*; cursor changes its shape. Point cursor on some line and click left button. The line you are pointing at becomes red and picture in the profile view window changes as well. This is the way you can directly inspect profile information by picking the line you want to see from your map. You do not need *Profile browser* dialog, close it for now.

   The next step shows how you can tie points on the profile with points on the map. You perform it by setting markers on the map which in turn appear in the profile view or by settings markers on the profile view which automatically appear on the map. There are two pre-defined markers (arrow up and down). When you set the marker first time it shows it as arrow up; when you do it second time it shows it as arrow down. When you do it the third time the first arrow up goes away and a new arrow up appears in the new place and so on. Try the following next:

   - In the profile view window, go to *Edit/Set marker.* The cursor changes its shape to $+$; go to some point on the curve and click left button. ”Arrow up” arrears on the curve. (note that the marker can be set only in at the location where you actually have X,Y, Z data). Inspect the red line on the magnetic map. You will find the ”arrow up” there.
   - In the map window, go to *Edit/Set marker*; cursor changes its shape and it becomes $\odot$. Point its center to some place on the red line (the profile you are seeing in the profile window). Click the left button. The sign ”arrow down” appears on the map. Go to the profile view and find the same mark there.

- Repeat the above operations several times to become familiar with it. Note that at some extreme points in the profile view you may not see some types of markers. Zoom to part of the map window where markers are located. See that they appear on all map views. Note that in the map view you can set markers on an active profile line only. They do not go away from this line when you change lines.

5. **Another approach to grid profile data.** You can see from the map we have just interpolated that some anomalies appear as wide points on the profiles. They do not look realistic. This is a property of the interpolation method (the interpolation problems are generally quite complex) and might be improved by tuning parameters in the interpolation box. You can try for example different values for *Tension*. Tension 0 corresponds to "a minimum curvature" solution and the value 1 gives a harmonic solution. Reasonable values are about 0.25 - 0.8.

   But there is another way of interpolation as well. We can triangulate data points and then do linear interpolation inside triangles to find data value for each grid point. **MagPick** provides this way also. You will see how it can be done.

   In the profile view window, go to *File/Interpolate grid/Triangulate*. The dialog box *Triangulation parameters* appears on the screen. This dialog has many parameters. Here is what to do next:

   - Under *X parameters* check *Data limits*. This means that the horizontal extent of your grid will be taken in accordance with minimum and maximum values of X coordinate in the data.
   - Under *X parameters* set interval 0.25. This is your grid cell size along X axis in the grid we are going to interpolate.
   - Under *Y parameters* check *Data limits*. This means that vertical extent of your grid will be taken in accordance with minimum and maximum values of Y coordinate in the data.
   - Under *Y parameters* set interval 0.25. This is your grid cell size along the Y axis in the grid we are going to interpolate.
   - Check box *Filter data (recommended)*. This means that before triangulation, the number of your data points will be reduced. If a few of initial points fall into one grid cell, only one will be taken (or some combination of points). This is recommended because if data has duplicated points there will be a problem (the program even can crash). Set *Method* as *Average value* and *Format:* as *GS ASCII*
   - Finally change the file name to `g-858mt.grd` where "t" stands for "triangulated"

   This is a bit faster than spline interpolation. We end up with a file g-858mt.grd on the disk.

   Now again go to *File/New* and select "Grid view". In the empty window you can check settings in *Options/Settings* and *Options/Size* or go directly to open and pick file `g-858mt.grd` (you do not need to close your old map view). Compare these two pictures.

6. **Draw stack profile.**

   Up till now we could see the profile data in a separate window. Now we will combine the profile information with a map to see them simultaneously. In the map view, go to *Options/Settings* Click two times on *Show profiles* (till window *Profile plot parameters* appears on the screen) Inside this dialog:

- Check *Show profile direction* and set *each 200 pixels*. This will allow **MagPick** to show the direction in which the profile was taken by arrows each 200 pixels along the line. The direction is defined by the data order in the original file (and therefore will be opposite to the real direction in the case of G-858 data because this device reverses order of magnetic readings)
- Check *Plot stack profiles.* This means you want the feature added to the map.
- Set *Datasets to draw: 1* In many cases it will be 1, so do not change this value.
- Set *Data scale: 100*. **MagPick** has to transfer ”data values” to ”position values” to plot stack profiles and therefore it has to scale ”data values”. To do this **MagPick** divides data values to the number you have just entered. To increase the span of the anomalies on the final plot you decrease this number and vise versa. For example 50 will increase anomaly span 2 times.
- Select *Type:* as *Fixed direction*. This means that positive anomalies will be drawn to the direction specified (clock wise). Enter 90 degrees as *Fixed direction azimuth*. Other choices are *End points* and *Normal to path*. *End points* selection means that two end points of each line are used to calculate the stack profile azimuth. *Normal to path* selection means that at every point the stack profile plot is perpendicular to the path.

  Preferred direction is the azimuth to where positive parts of the anomalies will gravitate. This is useful when you have parallel lines taken in two opposite directions and you want the positive part of the anomaly to be drawn on the same side of the XY line.
- Choose *Fill type: positive* and fill color you like. Say, green.
- Do not check *Clip stack plot* for now. This feature allows clipping values on the stack plot which are bigger or less then certain limits.

Press Ok and to close dialog and then close *Common parameters.* too. You can see now a map overlaid with the stack plot. Do it one more time filling in negative anomalies.

To see the stack profile plot better you may want to get rid of the color map. To do so *Options/Settings* and uncheck *Color map*. Press Ok.

This raises an interesting question. In some cases you are not able to produce a quality magnetic map but still want to operate with profiles. This means we need the views we discussed in this section. The background for these views is the map. To resolve this situation **MagPick** creates a fake map to serve as a background, which is never displayed. For instance you could load profile data without loading the map. Then go to *File / New* and select *Grid*. **MagPick** shows positions of the profiles using dummy map.

Alternatively you could load any other map to serve as a background. It is common to load bathymetry map (in marine surveys) and display stack profiles on top of it.

7. **Advanced feature - how to add something on top of magnetic map**

   In many cases we need to see some geometrical (topographical) information on top of the magnetic field. This paragraph is a hint how you can do it.

   Additional information comes in wide variety of formats (like USGS DLG, AutoCAD DFX, DLG, ArcInfo files, etc). It is beyond **MagPick's** abilities to support all this world of digital data. Instead MagPick offers its own but *very* simple format for external features. It is your responsibility to transfer your data into this format. For example there is a way how to transfer

essentially any picture presented as PostScript file into MagPick representation (this is not easy, involves outputting some ”simple” form of PostScript and then parsing it and scaling with your own shell script). But here is just a simple example which does not involve the transformation questions.

Do next:

- With your favorite ASCII editor (in many cases it will be the ugly program called `notepad`) create a new file, say `line.dat`.
- in this file type:

```
> UTM GRAY 5
10 10
10 70
70 70
70 10
10 10
```

  The sign > should be in first position and you have to press the cartridge return after last string. Save this file.
- In the map view go to *Options/Drawings*; press the button *Add*; select *Type of the file: Lines*; press OK; select your file `line.dat`. Then press OK once more.
- You should redraw the picture in order for the changes to take effect. Go to *Edit/Redraw*. A fat grey rectangle appears at the left bottom corner of your map.
- It’s probably too fat. Use your editor in `line.dat` again and change `> UTM GRAY 5` to `> UTM GREEN 0`. Save file. Redraw the map.

This way you can virtually present any vector information on top of the magnetic map. Keyword ”UTM” stands for UTM projection. This means that coordinates in the file are expressed in UTM. Other keyword is ”GEO” which means that position are represented by longitude and latitude. Because **MagPick** normally operates with short form of UTM projection proper UTM parameters should be set to allow program conversion from longitude and latitude to Northing and Easting.

See the full manual for complete set of features and format description.

12.4 Detecting of magnetic bodies.

Goal: MagPick was no originally designed as a visualization tool but rather as an instrument for locating of magnetized objects. This tutorial shows how you can use **MagPick** as alocating tool. do it. This introduction section is very simple: it explains why **MagPick** is called ”MagPick”.
Files: As an example we will use the magnetic field of a real bomb from World War II: GP 500 ISS (UK), General Purpose 500 Libs, excavated out of Kuhwerder hafen (Hamburg, Germany) in September 1997. Its mass is 226.5 kilograms; the field was measured with G-858 magnetometer (two sensors - top and bottom) on grid $17 \times 20 meters$. Susceptibility was estimated as 0.87 cgs, and remnant magnetization as 0.24 gauss (we will not discuss here how it was done; see rest of the manual for that) Files we need are located in subdirectory `\bomb`.

1. **Simple pick of magnetic object.**

   Start **MagPick** and load file `bomb.grd`. It has just 35×41 cells; go to *Options/Size* and set the size of X,Y cells as 10. Now you can see it better. If you turn off the color equalization (Go to *Options/Settings* and then *Change Palette/Uniform* and uncheck *Equalize color*) you are seeing a classical field from a magnetic dipole. To make life better set the coordinate grid with steps of 2×2 meters. Ok.

   Now where is the object is really located? There are minimums and maximums on the map in front of you. Simple theory predicts that object somewhere in between on the line which connects these two points (say, half a way). So we can now locate it.

   Go to *Edit/Simple pick*. Cursor becomes $+$. Go where you think maximum is, click the left button. Now the dashed line is started at that point and follows the mouse. Go where you think minimum is. Click again. A solid black line segment appears. This is the ”magnetic pick”. Perfect! The middle of that line is probably where bomb is.

   Now it’s time to explain some points in the *Common parameters* dialog box: if you check *Snap to grid* then start and end points of the pick are snapped to the middle of nearest grid cell If you have worked with Corel Draw or Surfer this should sound familiar. If it is not checked they stay where you set them. Check box *Show crosses* enables you to draw small oblique crosses at the end of the pick. Try these two features to see how it works.

   To see the cells better you can zoom into part of the map. Note that when you do picks they appear in all widows which represent the same magnetic map.

   Certainly you can save and use this information.

2. **More advanced: Rectangular pick.**

   The action we just have taken with a simple pick has a problem. We used our eyes to find where maximum and minimum were located. MagPick can do it for you so you do not have to stare at screen. This is the procedure:

   - Go to *Edit/Rectangular pick*. The cursor changes its shape. Now go to point 6,12. Look at the bottom of the main window to read coordinates. Note that it says *First*. Press left button and drag the mouse down and left. (up to point 10,8). Release mouse. You have just showed **MagPick** the area to search for maximum field.
   - Move the mouse and look at the status line, It now says *Second*. This means you have to show MagPick the *second* area where the minimum is located. Go to point 6,14 and repeat the operation (drag to point 10,10). As soon as you have released the mouse button **MagPick** connects the maximum point in the first area and the minimum point in the second. You may note that this pick differs from what you did by hand.
   - Important! You must show the maximum area *first* and minimum *second*. Areas can overlap.

3. **Removing the pick.**

   Consider we did a pick by mistake and we want to get rid of it. Go to *Edit/Delete pick*; then move mouse to the middle of the pick you want do delete; click the left button. It’s gone.

   Remove all picks you have done and make a new, ”clean” one.

4. **Saving and loading of pick file.**

   We certainly want to keep this information. Go to *File/Save pick* and select a file, say `pick.out`. Press Ok (Save). Exit MagPick, start it again and load the file `bomb.grd`. Go to *File/Open pick* and select `pick.out`. We have it again! You can interrupt your work, save your picks and resume it later.

   You might be interested in looking at the `pick.out` file with an editor (probably `notedad`). Each string in this file represents a pick. I will not explain all the fields in that string (see the complete manual for that) but here is what's important:

   - Last number is always 0.000 - you do not need it.
   - Two numbers before the trailing 0.000 - horizontal (X and Y) position of the middle of the pick. You are probably interested in this point.

5. **Notes about picking.**

   It's a tedious process if you have a large field. You generally should not work with the whole map at once. Instead, zoom into different places to see them better, pick anomalies there, the close the zoom window and go to the next place. Certainly you should cover the area gradually, say west to east and north to south. In some cases (if shape of an anomaly is complicated) a rectangular pick is not what you need, you have to go with a simple pick.

   The result of your picking is a table with X,Y,Z locations you want to check. (with digging or diving). The pick file also holds the minimum and maximum values for the field at the pick's ends. You can use these values to classify your points.

   MagPick also offers automatic picking. See main manual for this option. You should inspect results of automatic picking before accepting them.

6. **Pick export.**

   MagPick allows converting picks into its internal drawing format for usage as a base map. Pick can be also saved in SURFER "dat" format or exported in a very primitive form of AutoCAD DXF file. No guarantee your software will read it. If it will, you might have to scale the picks to fit them on existing maps.

12.5 Finding magnetic dipoles

Preface: Many local magnetic bodies can be approximated with a simple model: uniformly magnetized sphere (magnetic dipole). This simple source has only six parameters to be estimated by the interpreter: these are X, Y, Z location of the center and J_x, J_y and J_z components of magnetization vector. **MagPick** does not consider the dipole as one which has only induced magnetization (in this case $\vec{J}$ would be parallel to the direction of the Earth's magnetic field). It includes remanent magnetization into consideration and therefore total magnetization is represented by an arbitrary vector $\vec{J}$.

Modern magnetometers measure *total field* which is the projection of an object's own magnetic field into direction of the Earth's field. Therefore for proper parameter estimation we should know direction and value of the Earth's magnetic field in the area we are working in. There are some models and tables which can be used to find these values. The well-known IGRF program is one of them. (IGRF stands on International Geomagnetic Reference Field; see for example IAGA Working Group

V-8 (1995). International Geomagnetic Reference Field, 1995 revision. Submitted to EOS Trans. Am. Geophys. Un., Geophysics, Geophys. J. Int., J. Geomag. Geoelectr., Phys. Earth Planet.Int., and others.) **MagPick** includes IGRF model for easy computation of Earth's magnetic field elements.

MagPick is capable of estimating of total magnetic moment of the object. Dependence between magnetic properties and mass is quite complex and based on remanent magnetization J_{rem} and susceptibility κ. The last two values vary even for one kind of material. Nevertheless MagPick tries to find mass based on these two values, but results are not so good in many cases because of wide range for J_{rem} and κ. This task is non unique, it has two solutions. So do not pay too much attention when you see some weird values for mass during **MagPick operation**.

Goal: We will learn how to find the position and magnetization of the point source(s) if we have a map of magnetic field.

Files: Use the file `bomb.grd` from previous lesson. We need parameters of the magnetic field for Hamburg, Germany: $T_{total} = 49011.nT, D = -0.1^\circ, I = 68.3^\circ$. Here D denotes declination, I denotes inclination.

Parameters of the object: $J_{rem} = 0.24cgs, \kappa = 0.87gauss, mass = 226.5kg$. [6]

1. **Estimation based on magnetic map.**

   - Start MagPick and load file `bomb.grd` Adjust the color and size to see teh picture better (say, set X,Y cell sizes as 10 pixels). You are now seeing a typical dipole anomaly right in in the middle of the window. In real life there are another objects near by, therefore we should constrain the area we are going to work with. Go to zoom (*Edit/Zoom*). Zoom the area from the bottom left corner 4, 4 to upper right corner 14, 16. You have now a second window, where we will do our operations.
   - Now use the rectangular pick (*Edit/Rectangular pick*) Show maximum area, then minimum area. The pick appears in the screen. The middle point of this pick is the *initial* location of the dipole. The mathematical solution needs to be given some initial geometrical position which includes X, Y, Z.
   - Go to *Inverse/Run*. Here you have to fill in the table. Specify *Man filed inclination,declination and azimuth of X axis* (latter is 90° degrees because X axis is going west-east). Enter *total magnetic field* and *Susceptibility, Remanent*. Let *Margin space* be 0, *Number of iterations 4000* (some big number), *Limit to stop* equal zero. Now important parameter is *Initial depth*. Set it as 5 meters.

     You should not set *Density* and *J scale* now. Make sure *Induced only* and *Linear only* are unchecked. Set *Grid type:* as *GS ASCII grd*. This is a well known Surfer ASCII grid format.

     Now change file names. Set *Position file:* to be `position.dat`, *Calculated grid:* (this is where synthetic field from the source is written) to be `calc.grd`, and *Difference:* (observed field minus calculated) `diff.grd`. Set *Object type:* as *Dipole(s)*.

     You are done here. Press *Start iterations.*
   - You will see a small progress window with *Iteration number* and *Discrepancy*. Discrepancy value is decreasing. When it stops decreasing (for these data it is about 3.6) press cancel. You have just found the magnetic source.

[6] To get mass estimated correctly, locate file "magpick.ini" (or ".magpick" on Unix systems) and make sure that string "IronDensity" is set to 0.0078

MagPick shows the horizontal position of your dipole as sign + with a number. To see it better zoom to the central part of the map and turn off the color map. You can see that it was not placed not on the middle of the pick but close.

- There is another form of data representation called the worksheet. Go to *Inverse / Worksheet / Dipoles*. You will now se a table with one row which represents the location of the source you have just found.
- Inspect the synthetic field. Create a new empty grid view and load file `calc.grd`. This file was created during calculation. You may need turn on the color map for that view. Compare the observed and calculated fields.
- Inspect the difference observed minus the calculated. If the case is a good fit it look like random picture. Again create a new veiw and load file `diff.grd`.

You have done well. The magnetic source (a very dangerous one in this case) was located. The real position was: X=8.5m, Y=10m and Z=2m. Compare these values with X,Y,Z in the worksheet on your screen.

2. **Stability of the solution**.

   We were able to find magnetic source but how stable is this solution? What should be the criteria to accept it or not? Basically there are two types of criteria:

   - What is the difference between the observed and calculated field? Which features of the observed field we can see as well the in calculated one? What is numerical difference ? These are the questions which should be answered. Therefore it is important to inspect the observed and calculated fields.
   - How stable is the solution? What happens if you completely change the initial location and depth of the source? Do you still get similar numbers? You should investigate this empirically.

   Here are five attempts with a completely different initial position and depth of the source (see figure 34). Table 2 shows initial depth of the source and estimated X,Y,Z locations.

Z initail	X	Y	Z	J total	mass
1	8.51	10.23	1.93	$8.5 \times 10^{+3}$	266.0
1	8.51	10.23	1.93	$8.5 \times 10^{+3}$	266.1
10	8.51	10.23	1.93	$8.5 \times 10^{+3}$	266.1
5	8.51	10.23	1.93	$8.5 \times 10^{+3}$	266.0
0.5	8.51	10.23	1.93	$8.5 \times 10^{+3}$	266.0

Table 1: Results of different attempts to find a dipole

You can manipulate this data testing the results. Delete your pick, change mode to *Simple pick*; make the pick somewhere else. Then start the inversion. Change initial depth as well. You will find that this estimation is pretty stable. Of course there are some ways to confuse MagPick on this data, for example, set the initial depth as zero.

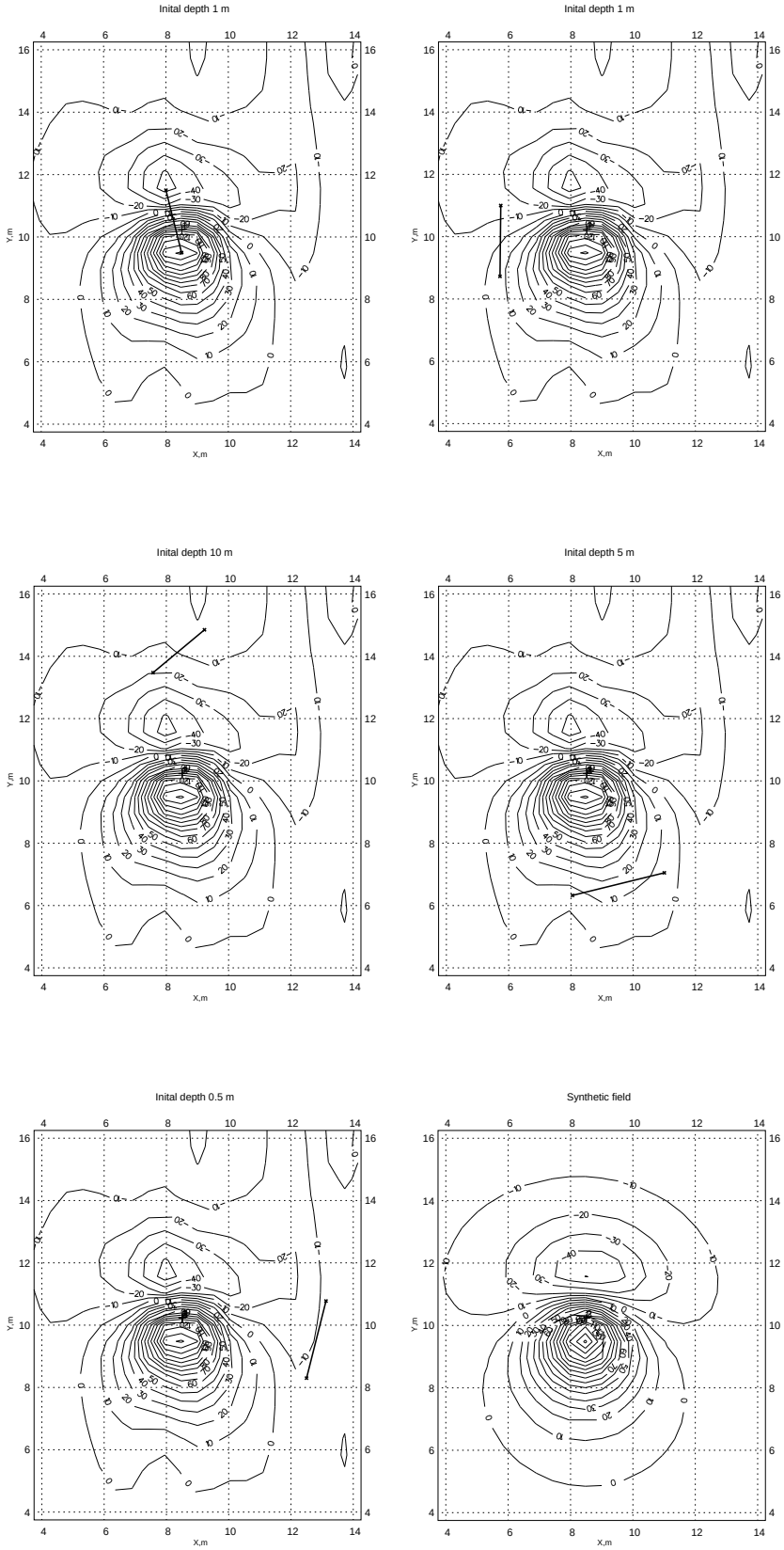

Figure 34: 5 attempts to find a dipole.

3. A solution based on profile data.

   So far we have used only an interpolated magnetic map to find the position of the dipole. Generally speaking this map is not always true. If the spacing between data points is large the interpolation procedure fills in the cells in between. These interpolated values may not reflect the real behavior of the magnetic field. However these values will be used in case of grid based interpretation.

   As you already know MagPick allows you to read profile data. It also can use the profile data for finding magnetic dipoles. To investigate this do the following:

   - Load file `bomb.grd`.
   - Go to *Profiles/Load list* and select file `bomb_bot.lst` 19 profiles line are loaded. Redraw the picture to see the profile lines.
   - Now go again with the zoom and enlarge area with corners (4,4) (14,16) as we did before.
   - In a new window, go to *New* and choose *All profiles in the window*. Note that all profile lines in your map window become red. This means that you are seeing all these lines simultaneously in the profile window (not one by one as we did in the *Profile view*) and this new window has the word *Inversion* in its title.
   - Adjust the profile view parameters. Go to *Parameters/Settings* and set *Type: Along Y* (data were taken along Y) You are looking at a classic dipole field.
   - Let's work with this now. Go to *File/Browser*; you can see that *all* lines are selected. Press the button *Deselect All*. Now view window is empty. Select some lines from the list. You see that you are able to select more than one line. When you click on an already selected line it gets unselected.
   - Some explanation should be done at this point. This new profile window we are working with now is the counterpart of the map window from what we called *New/Profile inversion*. Only one such window can be opened per one map view window. This *profile inversion* window has some extended properties. It can display more than one profile, it shows the data as function of direction, and it can use the profile data for inversion.
   - Press *Deselect All* now. Go to the magnetic map window, choose *Edit/Pick profile*, pick several profiles which cross the magnetic anomaly. Check that you can see them on the profile inversion view.
   - On the magnetic map, go to *Edit/Direction*. Point the mouse somewhere in the middle of map window. Click left button, move mouse approximately 45° north east, and click left button again. The arrow sign is now on the map.

     Now go to the profile inversion view and set *Parameters/Settings Type:along pointer*. See how the picture changes. You are now seeing *projection* of your data on a direction you have shown on the map view. Zero is where arrow on the map view starts (it is marked by small ○). Now go to the map view and show another direction (do the same as for first arrow). The profile inversion veiw updates automatically to reflect a new horizontal axis.

     Return now to *Type: Along Y*.
   - In many cases we need to constrain the data we are going to use for an inversion. For the map view we did it by zooming part of the map. For the profile view we have a more flexible way. Select *Edit/Polygon* in the map view menu now. Go approximately to point

6.5,6 and click. Then go to 6.5, 14 click - 10.5, 14 click - 10.5, 6 click and again 6.5, 6 click. We have drawn a polygon (in this case a rectangle). Check the profile inversion view now. The data is cut. Only this piece would be used for the inversion. If you pointed polygon vertex by mistake you can undo this operation by clicking right button.

If you need to get rid of the existig polygon, just go to *Edit/Polygon* one more time. The polygon contour will disappear.

- It is time to work on the inversion itself. Make a pick on the map view. It will serve as initial location for the magnetic dipole. Go to *Inverse/Run* in the profile inversion view. Here is a dialog very similar to the one we already had for the map inversion. Change *Positions file* and *Output file*. Press *Start iterations*; wait till the discrepancy stabilizes; and press cancel.

  You can see a new location of the dipole on magnetic as cross $\times$ and number. You can inspect the results with a workshee. First worksheet column shows ”P” if this is result of profile inversion. The grid based inversion is shown with ”G”. On the profile inversion view you can the see result of calculations as dashed lines. See figure 35.

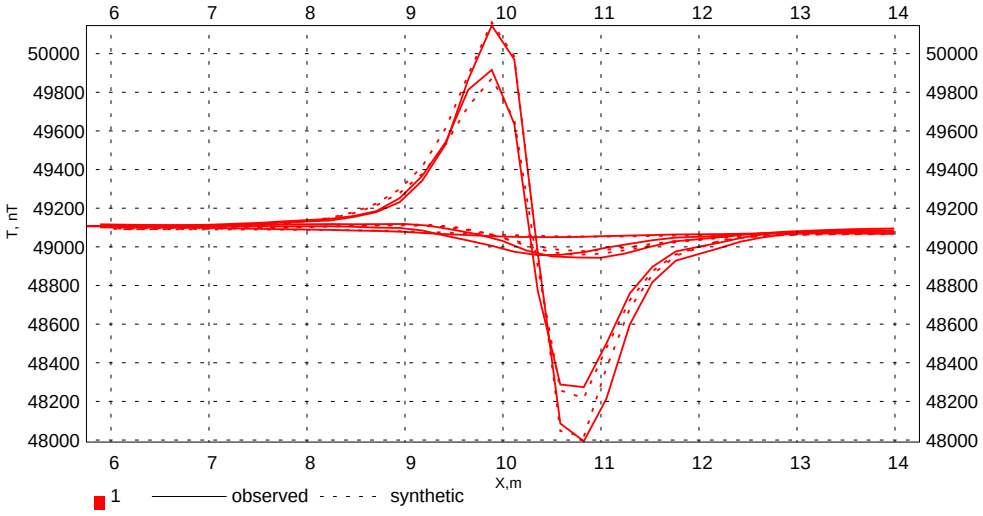

Figure 35: Inversion of profile data

Now we can work with the profile inversion as we did it with the map inversion. Note that nothing prohibits as from applying the map inversion. The results come to the same worksheet but it has ”G” in first column. Set the initial position / depth in the different places of the map and try to invert the data by profile inversion. You may note that MagPick reports depth about 0.6m Take a guess why ? (Hint: what was the separation between top and bottom sensor?)

You can note as well that when you set initial depth to less than 0.6, the process does not converge. This is because it’s less thanthe real depth of the object. It is recommended to start with the initial depth which is more thanthe conceivable depth of the magnetic source.

In general inversion based on profile data is less stable than inversion based on a map. It depends on profile distribution in space. For example if you are trying to find the position of a source which is aside from your profiles it might be unstable. The case when the source is between your profiles is much better.

4. **Worksheet operation**

   Results of the inversion are displayed in the worksheet window. Only one such a window (for example, for dipoles) exist and once you have opened this window you can not close it (it hides if you close it). MagPick worksheet window is not the same type as a worksheet in Surfer or Excel. It allows only some basic operations which are listed here. All functions are available by window menu and by pop up window (right mouse button).

   - Left mouse button - highlights current row.
   - **Open(Load)** Load file into the worksheet. The file should be a space or tab separated set of columns. You may need to redraw to see loaded data.
   - **Save** Saves worksheet content into simple ASCII file. When you have a large project it is recommended that you save your data from time to time.
   - **Delete** Removes current row from worksheet and from the map. Re-numerates dipoles.
   - **Undo** Operation opposite to delete. Restores eventually removed row.
   - **Export** Export worksheet content into form readable by other software. Presently there are two choices: Atlas Boundary and AutoCAD dxf files.

12.6 Finding magnetic pipes.

Preface: Some elongated magnetic objects like metallic pipes can be approximated with a simple source such as magnetized material line. This line is infinitely thin and has a magnetic momentum. This kind of source can be infinitely long or may have a finite length. It is certainly not a real pipe, but at the distances much greater than the pipe diameter it provides a good approximation.

MagPick employs this model for locating of pipes or similar objects. Practice shows that this kind of object rarely can be considered as infinitely long, therefore a simple infinite length approximation won't work. Things are even worse, most of the magnetic field observed from pipe sources are due to the section joints, not from the linear part of the pipe.

To cope with this problem MagPick provides several user-selectable modifications of search (see figure 36)

- **(A)** Simple segment with uniform magnetization. To be estimated: geometrical location in XOY plan (we assume constant depth for all segment) and 3 components of magnetization J_x, J_y, J_z
- **(B)**Simple segment with uniform magnetization and infinite ends. In addition to the properties of the central segment properties of infinite ends must be estimated too. This way we try to model a situation with final segment included into long pipe.
- **(C)**Equidistant parts with different magnetic properties. Magpick divides the pipe on number of segments with different magnetic properties and tries to find J_x, J_y, J_z for each segment. Number of segments are defined by the user. This should be used to model the case when just a few (1 or 2) survey lines cross over each pipe segment.
- **(D)** Equidistant parts with different magnetic properties and infinite ends. The same as above but plus J_x, J_y, J_z to be estimated into infinite ends.

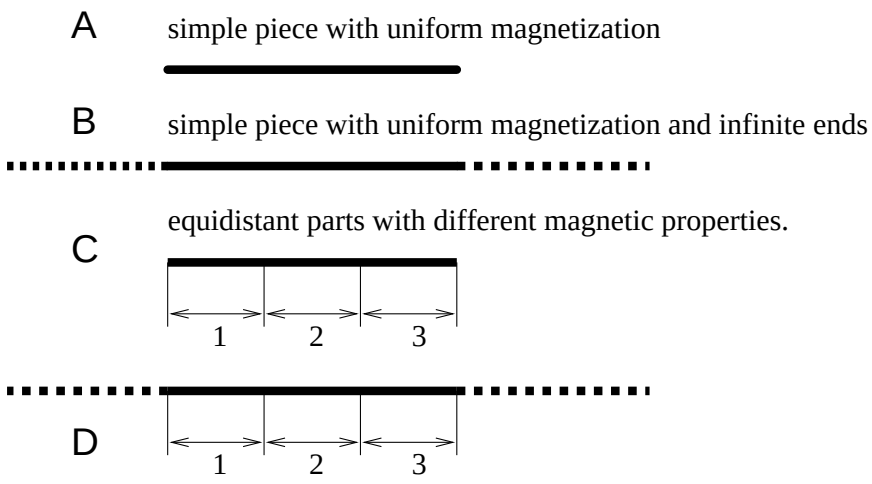

Figure 36: Modification of pipe model.

Similar to a magnetic dipole case the pipe determination can be based on gridded magnetic data or on profile measurements. Because of asymmetry of the object we would recommend primary usage of profile data. Interpolated (grided) magnetic data can contain considerable errors for this kind of a magnetic signature (this is of course function of area coverage).

Goal: Based on a simple example we will learn how MagPick can be used to find the location of the pipe segment. We will use case **(B)** based on profile data.
Files: under `tutor/pipe`. Find here file `dummy.grd`, `line1[5].dat`, `lines.lst` and file `field.txt`. The last one holds the parameters of the Earth's magnetic field for a place where data was taken. File `lines.lst` is a ready list to load into MagPick.

1. **Start MagPick and load all information.**

   Start MagPick. Before doing anything else go to *Options / Settings* and make sure that *Color map** and *Contours** are not checked. We are not going to use the map in this tutorial. We will load the "dummy" grid (it is worth checking file `dummy.grd` with the ASCII editor). Set coordinate grid steps to 100 m for X and Y. Press Ok. Now go to *File / Open* and pick file `dummy.grd`. An empty grid appears on the screen. The size might be to small. Go to *Options / Size* and set *X-cell, Y-cell* as 5 and enlarge window to see whole area. This is our empty map.

   Now go to *File / Profiles / Load list*. Select file `lines.lst`. MagPick reports that 6 profiles were loaded (in this case each profile is represented by its own file). Press Ok. You can now redraw the picture (*Edit / Redraw*). If this is not what you wanted go to *Options / Settings*, click on *Show profiles* to invoke profile configuration dialog. Here check *Plot stack profiles*, enter *Datasets to draw:1*, enter *Data scale:10* (this is value magnetic field divided by before plotting). Check as well *Use fixed direction* and enter *Fixed direction azimuth: 55*. Choose *Fill type: Positive*, fill the color you like and uncheck *Clip stack plot*. We are done, press Ok. (and one more to close *Common parameters*). You should see stack profile plot now.

2. **Profile inversion window.**

   If you try to start an inversion procedure from the map window then the map data will be used (in this case it does not make sense because there is no real map data). If you start it from *All*

profiles in the window then the profile data is used. This is what we want. All profiles window is a counterpart to the map window. There is just only one allowed per one map window. Look at figure 37. There is a map window on the right side of the screen and a profile inversion window on the left side.

From a map window go to *File / New* and select *Profile inversion.* A new window pops on the screen (and all your profile lines in the map window become red). You are now seeing all the profile data in your map window as graphs T(x). To adjust view do the following:

- In the map window, go to *Edit / Direction* Draw direction as it is shown on 37 (3). Click first point, move to the second and click again. Arrow is drawn.
- In the profile inversion window, go to *Parameters / Settings*; choose type *Along pointer* and press Ok. Now you are able to see all anomalies from pipe at the same place. They were projected on direction you have shown.
- Change range for profile inversion view. If you draw an arrow like it is on figure 37 then in the profile inversion window go to *Parameters / Settings*; uncheck here for *Xmin: Xmax: Data limits* and enter *Xmin:-100* and *Xmax: 100*. Now the horizontal axis extends from -100 to 100 m.

3. **Constraining data used for locating.**

   We definitely do not want use all data presented in the map window for location of a single pipe. To restrict the data do the following. Under map window, go to *Edit / Polygon*, then go with the mouse to the point 5800, 2800 (approximately). Click the left button. Draw a polygon as it is shown on figure 37 (4). Close polygon by hitting the first point one more time. If you clicked the left button by mistake the last node can be removed by a right click. Choosing *Edit / Polygon* removes current polygon completely.

   As soon as you draw the polygon your profile inversion window changes too. It shows only data inside the polygon (try for example to draw very narrow polygon and see what happens).

4. **Defining initial pipe location in XOY plan.**

   For a non-linear inversion we have to define the initial location of the object. In MagPick *Simple pick* serves for this. Go ahead and set the pick as it is shown on 37 (5) (for the first try you even can set it close to anomalies). Opposite to the dipole inversion, pipe inversion allows just only one pipe at once (for dipoles you can have several of them estimated simultaneously).

5. **Profile based inversion.**

   Now we are almost done. In the profile inversion window, go to *Inverse / Run...* Here you should enter Earth's field parameters:

```
Total Intensity :  35178.03 nT
Inclination     :     37.80 deg
Declination     :    351.84 deg
```

   Other important parameters are: *Azimuth of X axis:90, Number of iterations: 4000* (big enough) *Limit to stop:0. Initial depth* is very important parameter. Set as 5 for instance. Change files as you need, but this is not important now.

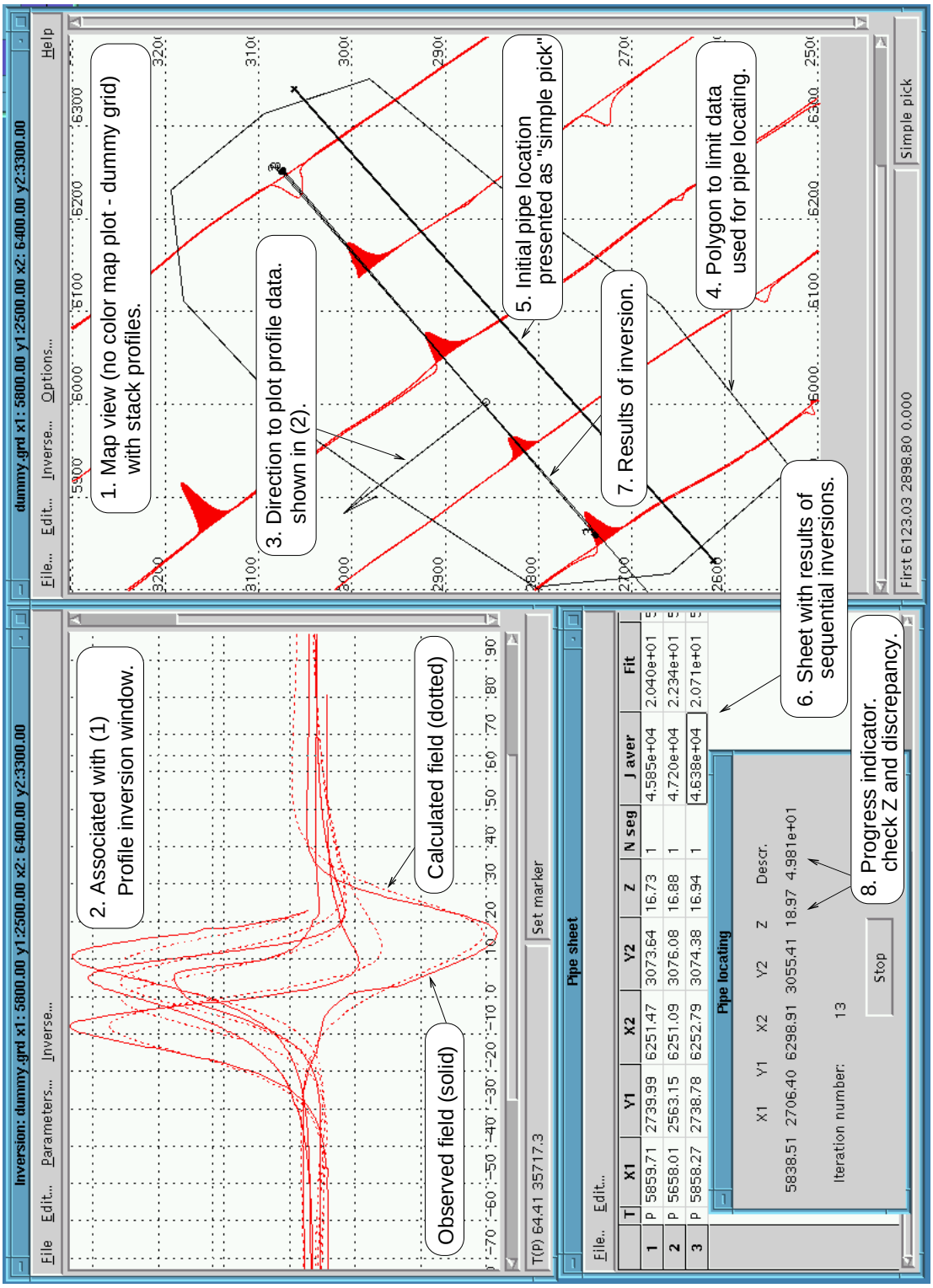
1. Map view (no color map plot - dummy grid) with stack profiles.
2. Associated with (1) Profile inversion window.
3. Direction to plot profile data. shown in (2).
4. Polygon to limit data used for pipe locating.
5. Initial pipe location presented as "simple pick"
6. Sheet with results of sequential inversions.
7. Results of inversion.
8. Progress indicator. check Z and discrepancy.
Observed field (solid)
Calculated field (dotted)
Pipe sheet
Pipe locating
Stop
Simple pick

Figure 37: Finding pipe location with MagPick

Set *Object type:* as *Pipe* and press *Object specific*. Here set *Number of pipe segments* as 1, and check *Use infinite approximation.*. This corresponds to the case (b) from figure 36. Press Ok and press *Start iterations...* Now the program is calculating. Watch the progress indicator (8). The last two numbers arethe most important. They are the current depth and discrepancy. The last one should decrease. Wait till it finishes. For pipe inversion you normally do not have to press *Cancel*.

As soon as it is done a new (dotted) lines appear in profile inversion window. This is the graph of *calculated field*. You can compare it with observed one. If the fit is good you can keep this result. If not, it is better to remove result of alst estimation and try again (for example with different initial depth).

6. **Results of inversion.**

   For dipoles you can see results of inversion in the worksheet. There is another (different from dipoles) worksheet for pipes. Go to *Inverse / Worksheet /Pipes*; window with results appears on the screen (6 on figure 37). Once opened it can not be closed. The pipe worksheet supports the same set of operations as the dipole worksheet: loading / saving from file, deletion of the raw, undo deletion, export as DXF or BLN format.

   The results of inversion is also shown on the map view as $^{5}\bullet\!\!-\!\!-\!\!-\!\!-\!\!-\!\!-\!\!\bullet^{5}$ where 5 denotes estimation number (the same as row number in worksheet). It is shown on figure 37 as (7). When you remove the row from the worksheet it is automatically removed from the map view too.

7. **Estimating stability.**

   I strongly encourage you to try different estimations with a different initial location / depth. This way you can get an idea how real your estimation is. If the program ends up with the approximately the same numbers this means everything is Ok. If not you might conclude that you are unable to find this object (perhaps this object is not a pipe). This is also a possible result.

   You may note that the estimation procedure here is less stable than one for the dipole. If you set the initial location far from real and/or with weird initial depth procedure is likely to fail.

Conclusions Hopefully you have learned how pipe parameters can be estimated using MagPick. I would like to stress that this feature has not been in wide use. It appears much less stable than the dipole estimation. I would recommend to use it only when there is a clear field picture (as presented in this tutorial).

12.7 Reduction to the pole.

Preface: It is a well-known fact that the total magnetic field measured at a arbitrary latitude and longitude can be reduced to the field measured ”on the magnetic pole”. To do this kind of transformation the user should know the magnetic inclination and declination at the point of measurements (use IGRF model to find it). Also the direction of the body’s magnetization is needed. This last value may not be known, however in some cases it can implied that the body has only induced magnetization and therefore it’s direction will coincide with the direction of the Earth’s magnetic field.

This tutorial presents a numerical illustration of the procedure. As an example a field from a rectangular object with only induced magnetization has been calculated (see a.) on figure 38). Then

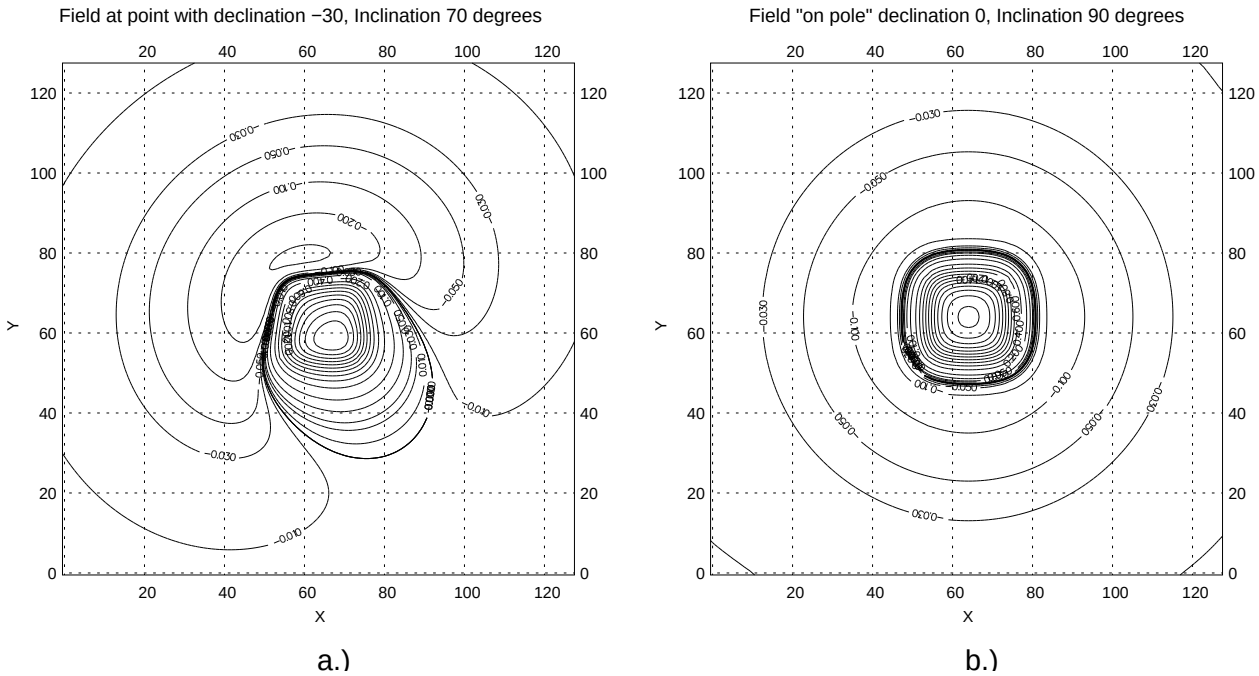

Figure 38: Reduction to the pole.

this field was reduced to the magnetic pole (plate b.) of the same figure). As you can see the anomaly has now a perfect symmetric form.

Goal: Illustrate how reduction to the pole works with perfect (model) conditions.

Files: for that lesson we take file `i70_d30.grd` under `on_pole` subdirectory.

1. **Load data file.** Start magpick, go to *File / Open* and pick file `i70_d30.grd`. Adjust size and color scale as needed.

2. **Make reduction** Go to *Operations / Reduction to the pole* Reduction dialog appears on the screen. Here set next:

   - Main field declination (D) -30 degrees.
   - Main field inclination (I) +70 degrees.
   - Declination of magnetization: -30 degrees.
   - Inclination of magnetization: +70 degrees.
   - Azimuth of local X axis: +90 degrees.
   - Check box *Use reduction to the pole*. Note than all for values below this check box are filled in automatically.
   - Set elevation and regularization parameter to 0.
   - Press button *File with transformed field* and pick folder and name for output file. Let's name is `on_pole.grd`. If you want this name to appear in the history list check *Add files to the history list*. Set format up with *Format* control.
   - Press *Ok* button to start calculation. Progress bar on the screen show the process.

3. **View results.** As soon as a calculation is completed you have two choices: go to the *Files / Recent files* and pick you file (if you checked*Add files to the history list*) or simply open a new window and load the calculated file. Examine the result of calculation in a new window.

Exercises: Try to recalculate this field with different directions of the magnetic field and magnetization. To do so uncheck *Use reduction to the pole* button and enter for example new declinations and inclinations as zero (case of magnetic equator) and see what you get.

13 Acknowledgments.

I thank everyone who participated in this project by using or testing MagPick. My many thanks to Dr. Jannis Makris and Rainer Kasig from the University of Hamburg who has inspired this program.

My special thank you to Dr. Dennis Wilkison, my boss at ”Geometrics”, who sacrificed his spare time checking and editing this manual. Without his effort this software would never been released to the public.

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